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Report

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MORNING SUBJECT (f)

DISCUSSION OF METHODS OF IMPROVING THE INTERCHANGE OF SCIENTISTS THROUGHOUT THE EMPIRE, INCLUDING A DISCUSSION ON THE FUTURE OF THE SCIENTIFIC LIAISON OFFICES THAT HAVE BEEN ESTABLISHED DURING THE WAR

STEERING GROUP

Chairman—Sir Alfred Egerton, Sec. R.S.

Recorder—Dr W. B. Mann

Dr D. M. Blair
Sir Jnan Ghosh
Dr C. J. Mackenzie
Dr E. Marsden, F.R.S.
Sir David Rivett, F.R.S.
Dr J. Smeath-Thomas
Mr F. E. V. Smith
Sir Henry Tizard, F.R.S.

REPORT

The need for increased mobility for scientists throughout the Commonwealth if the pre-eminent position of science in those territories is to be maintained was strongly urged at this particular discussion. Various ways of improving the machinery for interchange were discussed.

Several delegates from the Dominions urged that there should be more frequent short visits by leading men of science and specialists in various branches. Such short visits, whilst perhaps not contributing much directly to research, were of great importance psychologically, both by giving encouragement to young research workers in outlying fields and by maintaining the public appreciation of scientific effort.

Of paramount importance, however, was the need for providing research grants to enable recently graduated students, as well as more senior scientists, to obtain experience in universities and scientific institutions overseas. For scientists in established positions, such as those on the teaching staffs of universities and research workers, in government laboratories, the system of leave for study and research should be made more available.

For these purposes the primary requirement was the provision of funds with which to supplement existing resources and to meet expenses of travel, much of which will be by air.

A paper giving much information about existing travel grants and facilities was presented and it was felt that such information should be made permanently available in some centre for scientific information which should be established for this and similar purposes. (See Note.)

Particular stress was laid on the special opportunities existing in the Dominions for field work in the biological, geophysical and allied sciences, to supplement facilities already existing in Great Britain, and the need for provision of funds in order to make it much easier for the scientific worker to use these opportunities.

An account was given of the British Scientific Liaison Offices established during the war to maintain scientific and technical collaboration between the allied countries ; suggestions were made for the continuation and extension of these offices in the service of the peacetime scientific community. These offices had been of great value in facilitating visits and the movement of scientists.

Special reference was also made to the difficulties experienced by scientific

workers in the Colonies, where they are often completely isolated from discussion with colleagues.

The Conference decided to recommend that detailed consideration should be given to the need for finance, for the improved interchange of scientists, for the necessary increase in scientific staff, for the use of the Scientific Liaison Offices for administering schemes for travel, and for means of providing information about scientific work in different parts of the Empire.

Note

A proposal that an Institute of Scientific Information should be set up under the auspices of the British Association was adopted at a conference on the Dissemination of Scientific Information arranged by the British Association and the Royal Society on 9 July 1946.

Recommendations

The Conference agrees that interchange of scientific staffs, both of universities and research institutions, is of vital importance to the maintenance and development of scientific research within the Commonwealth and Empire.

1. To promote such interchange the Conference strongly urges upon all the responsible authorities the urgent need for—
   - (a) adequate provision by universities and research institutions to enable the senior and junior scientific staffs to take periodical leave for overseas visits, both short and long term ;
   - (b) the raising of staff complements to a level sufficient to afford individuals adequate time for research and for study or for special leave without thereby placing additional burdens on their colleagues ;
   - (c) provision of the largest practicable number of travelling scholarships for postgraduate work (see also 2 (b) below) ;
   - (d) a system of adequate financial provision for travelling and subsistence allowances to avoid loss to the individual due to differences in living costs in different countries ; this is to apply both to members of university staffs and to holders of travelling scholarships ;
   - (e) the provision of resources to enable the invitation of scientists from overseas for short periods to advise or for collaboration in specific research projects ;
   - (f) the exemption of all travelling scholarships and allowances from income tax either in the country of origin or of reception.
2. To the same ends the Conference :—
   - (a) further recommends an official policy for continuance and development of a system of Commonwealth Liaison Offices as being an essential part of the machinery for facilitating interchange of scientists and activities connected therewith, and directs that the attention of the Official Conference be invited to the matter ;

(b) urges the need for the central compilation and publication of a list of scholarship facilities existing within the Commonwealth and proposes that the task be entrusted to whatever organization may be employed for centralizing scientific information services ;

(c) invites the attention of the Official Conference to the need for the adoption of a uniform superannuation scheme for the Commonwealth to facilitate transfers without prejudice to such rights ;

(d) notes with anxiety the serious handicap to interchange caused by the high cost of sea and air transport and invites the Royal Society to initiate action with the appropriate organizations to remedy the position.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Professor J. D. BERNAL

I think all scientists who have participated in the war effort have learnt how extremely valuable it was to be able to move about freely all over the world without having to bother with any of the usual formalities of travel, including the fares. It seems to me that in this question we ought to consider first and foremost the actual needs of science, and then try and find the quickest and most economical ways of satisfying them.

Scientific travel is required for three main purposes. Firstly to facilitate discussions between scientists in different parts of the world, a purpose that applies to all scientists, but particularly to scientists in the middle and senior ranks. Secondly to study particular phenomena in the field, which requires far more extensive travel and applies particularly to scientists concerned with geo- subjects ; these now certainly extend to physics, as in cosmic rays, and to all branches of biology, particularly ecology and disease studies. This need for travel affects primarily younger and middle stage scientists. Finally we have the need for travel involved in the necessity for young research workers to study abroad. This will include not only the need already stressed in the Conference for workers from the Dominions to come to Britain for study, but almost equally the need for students in Britain to go to the Colonies and Dominions to study phenomena that can only be observed in those countries. Granting these needs, it seems to me that we ought to consider the two questions of transport and maintenance separately. Personally, I should like to see the question of transport centralized and made the responsibility of governments ; in fact that all scientists, on showing a *bona fide* reason for travel, should be given the same facilities as government servants in similar circumstances. Where the need was for swift travel, as for attendance at conferences, air transport could be provided, but for longer periods slower methods would be adequate. It would be a great convenience if the central scientific liaison offices in Great Britain and the Dominions could be charged with arranging all travel facilities, as they did for scientists during the war. This would enormously simplify the administrative work needed and obviate the multiplication of research studentships, etc. As for maintenance, if a complete two-way movement is maintained, the actual total maintenance cost of the scientists, who have to live somewhere, would not be materially increased. This would be particularly the case if, in centres of study, provision was made for scientists' clubs or hostels with reciprocal hospitality arrangements between the various centres. Naturally there would be some extra expense connected with short stays, and variations in cost of living in different countries would have to be allowed for. But by and

large this could be met, as it is already met for government servants, by suitably adjusted allowances according to place and length of stay.

Dr S. L. Hora

Dr Hora felt that a Master's Degree was not sufficient for sending students abroad for training. At this stage, they did not possess sufficient knowledge of local problems and resources and often got ideas from abroad which did not fit in with local requirements. Even academic students with Doctorate Degrees had to be broken in for a year or so by actual work in the field to appreciate local problems.

METHODS OF IMPROVING THE INTERCHANGE OF SCIENTISTS THROUGHOUT THE EMPIRE, AND THE FUTURE OF THE SCIENTIFIC LIAISON OFFICES

By Sir SHANTI BHATNAGAR, O.B.E., F.R.S., Sir JNAN GHOSH and Professor P. C. MAHALANOBIS, F.R.S.

INTERCHANGE OF SCIENTISTS

IN India the advantages of interchange of scientific men have been recognized for a long time. The Government of India, the universities and the learned bodies have from time to time extended invitations to leading scientific men from abroad, particularly U.K. and U.S.A., and such visits have been highly appreciated by all concerned. The Silver Jubilee Session of the Indian Science Congress held at Calcutta in 1938 was attended by leading scientific men from all over the world, and but for his untimely death would have been presided over by Lord Rutherford. The record gathering on the occasion representing scientific workers from all over India reflected the value that we in India attach to personal contacts. The visits of distinguished men from abroad as guests of a university or some institute have invariably been highly appreciated. In addition to their giving lectures and participating in academic and research conferences, their advice has been frequently sought in various matters relating to organization of science teaching and research. The Government of India, the Indian Science Congress, the universities particularly the Punjab and Calcutta, the Indian Statistical Institute, the Indian Institute of Science, the India Meteorological Department have had recent opportunities of inviting distinguished scientists from abroad, and the opinion is shared by all that the exchange of ideas and intimate personal discussions were stimulating and did much to further interest in research, even though in some cases the visits were short. We are keen, therefore, that all that could possibly be done should be done at the earliest to facilitate visits of Empire scientists to India.

On the other hand, we are equally conscious that similar facilities should be available to scientists in India to go abroad and see the work that is being done in important centres of research. Previous to the last World War, Indian scientists used to visit mostly laboratories in Great Britain and Germany. There is a great deal of desire now for people to visit the U.K. and Canada among the Empire countries and the U.S.A. and Soviet Russia among others. Australia has recently made much headway, and there is every reason to believe that India will be anxious to establish closer contacts if favourable opportunities are provided.

The existing arrangements for inviting men from abroad and for Indians to go out are far from satisfactory. At present the procedure is for the

Government of India or some other body to extend an invitation which usually involves payment of travelling expenses, hospitality in India and an honorarium. The total expense reaches a figure which the universities and other bodies can afford only at long intervals. In this way the number of people we would like to invite becomes much restricted. On the part of the invitees the visit involves securing leave from their employers, and if the absence is for any long interval it may involve difficulties over leave salary, pension rights, etc. On the other hand, the Indians going abroad have for the most part to shoulder all their own expenses, including cost of passage, rail travel, hotel bills. All this works out to a considerable figure. The Government of India and most of the universities have fairly liberal leave rules for those proceeding out of India, but besides these there are few other facilities. The number of Indian scientists who have been invited abroad and paid expenses may perhaps be counted on finger tips. If the scientists and students going abroad from India have formed an appreciable number in the past (speaking of the pre-war period) it was due to the anxiety of the scientific men to keep abreast of latest developments and of the students to get the best training available, rather than to any special facilities provided by the countries visited. On the contrary the students going to the U.K. had almost invariably to encounter difficulties in respect of admission, residence and certain other matters which need not be specifically mentioned here.

The question of interchange falls into three categories. Firstly, senior men going abroad with a view to establishing personal contacts with leading workers in their own field and to keep generally in touch with latest developments. Secondly, younger men actively engaged in work who wish to make contacts with their opposite numbers in similar fields, and also to acquire knowledge of the latest developments in technique and instruments. Thirdly, students proceeding for research degrees. Of these three we are at the moment concerned primarily with the first two. It is clear that there is large room for expansion of facilities in both the categories. The number of even senior people who can afford to go abroad is very limited. Many more would be encouraged to go if better facilities could be ensured. The facilities required are mainly of two types : (*a*) cheaper travel, board and lodging, (*b*) more ready means of establishing contacts. These apply equally to senior men and younger researchers. In the case of the younger men the financial question becomes even more acute. Their means would not allow their bearing the cost of travel and residence abroad. Hence there is need for fellowships which could fully, or to a good extent, meet their expenses. It should not be forgotten that in a majority of cases these people will have their families to maintain at home and so only a small part of their leave salary will be available to them for their expenses abroad. For a country of the size of India, the fellowships available for visits outside is deplorably small (this leaves out of consideration the overseas scholarships being awarded during the last two years by the Government of India which are primarily for technical training and not for research). There is, therefore, urgent need for a large increase in the number of fellowships available. If the principle is accepted and strongly supported by the Royal Society it will greatly reinforce efforts made to induce the Government of India and industrial

magnates to make provision for funds. There will also be need for approaching the universities in India to bring their study leave rules in line with each other to secure uniform conditions for all. It may, perhaps, not be generally known that previous to the war the Italian shipping lines used to give very favourable rates to tourists generally and students in particular. The 'tourist class' accommodation given by them used to cost about 30 per cent less than that given by British and other lines for similar comforts of travel. In addition, for students enrolled in Italy at some specified universities and studying for more than a month or so, the Italian shipping companies and railways allowed a concession of 40 per cent on the fares. It may, perhaps, be said that while part of the concessions were undoubtedly offered with the idea of attracting outside currency and tourist traffic, the fact remained that the concessions resulted in good use being made of Italian lines by students and others. It would be a great advantage if facilities of this type could be available for scientists visiting empire countries as soon as conditions become more settled. The suggestion made in this connexion that some concession seats may be made available on air lines which are subsidized by the government, deserves to be explored fully.

Scientific liaison offices

Closely associated with the above is the question of scientific liaison offices. After the success achieved by the British Commonwealth Scientific Office during the war, there can hardly be any doubt as to the peace-time utility of scientific liaison offices. The Government of India have already accepted in principle that Indian scientific liaison offices should be established at London and Washington, although details yet remain to be settled. The suggestion made that all the various Commonwealth offices may be housed in the same building and may share common services like duplicating, photostating, etc., will be readily acceptable as it will ensure efficiency, economy and uniformity. For the present we would wish to start with only the two offices at London and Washington. But in course of time and with the experience gained in working these two offices, it may, perhaps, be possible to have offices in Canada and Australia as well. Conditions in South Africa are different, but it is possible that scientists may succeed where politicians have failed.

So far as the functions of these offices are concerned, they may perhaps be stated as below :—

(*a*) to establish contacts with the various research and industrial laboratories in the United Kingdom and the United States ; to obtain their published and, where possible, unpublished reports ; and to pass these reports or the information contained therein to research and industrial laboratories in India interested in the subject matter of these reports.

(*b*) to act as channels of communication in the reciprocal process of obtaining reports issued from research and industrial laboratories in India and to pass these reports or the information contained in them to laboratories in the United Kingdom and United States of America interested in their subject matter.

(*c*) to collect detailed information regarding the facilities available at the universities, research institutions and industrial establishments of the United Kingdom and the United States of America, for the training of Indians in science, technology, industry, agriculture and medicine, and to arrange for their admission in the most suitable institutions in these countries.

(*d*) to arrange for the periodic interchange and visits of research workers between India and the United Kingdom and the United States of America, and to provide information as to the institutions where these research workers may most suitably carry on their work.

(*e*) to make inquiries on behalf of the Central Government, the Provincial Governments and the universities in regard to experts and specialists who may be required for employment in India on a contract basis for the promotion and development of pure science, and to negotiate terms of employment with the selected persons. It is recommended in this connexion that in order to avoid overlapping and competition, all inquiries of this nature should pass through these offices, the appointing authorities stating the qualifications of the experts required by them, and reserving to themselves the right of making the final selection from amongst the men recommended by the liaison office.

(*f*) to assist research institutions in India in obtaining information regarding special scientific apparatus, journals and books.

With regard to pay and other conditions of service the matter will have to rest with the respective governments but suggestions could be made by this Conference with a view to ensuring uniformity in pay, allowance, travelling, conditions of service, duration of tenure, etc., of the liaison officers and their staff. There may, perhaps, be some general agreement also on the number which each country may depute.

Proposals are before the Government of India for the appointment of four officers to represent the following branches of science :—

(*a*) agriculture
(*b*) medicine and public health
(*c*) mathematics, chemistry and physics
(*d*) engineering and technology.

In India the Medical and Public Health Department have under consideration arrangements to set up an Indian medical research liaison committee attached to the India office. The Agriculture Department is also contemplating a similar scheme. If these committees are appointed, one member from each could serve on the liaison office. The scientists will, however, prefer one scientific office which will have representatives of both Public Health and Agriculture Departments.

In view of the very wide range covered by each of the main subjects with which the scientific liaison offices will be concerned, it will be necessary for them, if they are to fulfil their functions efficiently, to arrange with other liaison missions to pool resources where necessary. This course has been recommended by Professor A. V. Hill and by the Indian Scientific

Mission which visited the U.K. and U.S.A. last year. Mention may also be made here of the offer made by the Royal Society to the Secretary of State for India to set up a special committee of Fellows interested in Indian affairs for the purpose of advising the Indian Scientific Office on any special matter desired. The appointment of a committee of this nature would greatly strengthen the hands of the Indian Scientific Office in London and may quicken the pace of research activity in India.

METHODS OF IMPROVING THE INTERCHANGE OF SCIENTISTS THROUGHOUT THE EMPIRE, INCLUDING A DISCUSSION OF THE FUTURE OF THE SCIENTIFIC LIAISON OFFICES THAT HAVE BEEN ESTABLISHED DURING THE WAR

By W. M. HAMILTON, M.Agr.Sc., D.Sc.(N.Z.)

INTERCHANGE OF SCIENTISTS

INTERCHANGE of scientists may be interpreted to include :—

(*a*) The constant flow of graduates proceeding overseas for further study—often on post-graduate scholarships.

(*b*) Officers of research departments and universities of some experience proceeding overseas for further study at some university or research institute. Finance provided by fellowships or departmental funds usually suplemented by private resources.

(*c*) Officers on loan or exchange from overseas institutes.

(*d*) Visits by specialist or administrative officers for the purpose of surveying progress in their own special field, often arranged to coincide with specialist conferences.

Graduates proceeding overseas for further study provide a valuable link, and when they return have a broader outlook and have acquired new techniques and methods of approach. Numbers are largely governed by availability of scholarships. A considerable number of our most talented students go overseas and after completing their training find that suitable positions do not exist in the Dominion to utilize the special type of training they have received, or that emoluments in such posts are comparatively unattractive. This may involve a loss of talent to the Dominion but provided this is absorbed by the United Kingdom in a useful sphere it should not be a cause for regret.

The research worker with some experience of the particular type of problem to be met in his department or division is, in some ways, in a better position to profit from a period of study overseas. Ten scientific officers from New Zealand were overseas in the four pre-war years studying in the United Kingdom or United States of America. Consideration might however be given to more adequate provision of fellowships for this class of officer or provision of sabbatical leave as a regular feature of employment.

The number of overseas research officers working for periods of a year or more in New Zealand research institutes has been limited but the results have been very good. Officers in this category have included :—

William Davies, from the Welsh Plant Breeding Station, 1928–1929.
W. J. Wiley of the C.S.I.R., working at the Dairy Research Institute.

Professor J. H. Kolb, Professor of Rural Sociology in the University of Wisconsin (6 months).

Extended visits by senior officers are difficult to arrange but with suitable personnel may be an excellent method of establishing firm contacts between organizations and should be fostered wherever conditions permit. Such arrangements might be facilitated by agreement on such matters as superannuation payments, allowances, etc.

Visits by specialist officers should be as frequent as conditions permit and every opportunity should be taken of stressing to government or other controlling authorities the necessity for such regular visits, especially from an isolated scientific community such as New Zealand. Provision of a sabbatical year's leave as a regular feature of employment of professional officers would also greatly facilitate such visits. In the four pre-war years (1936–1939) New Zealand sent an average of five specialist officers overseas each year as delegates to conferences or on special investigations. The number of visits overseas by senior and specialist officers could, with advantage, be materially increased. If co-ordinated research programmes are planned it becomes essential.

Visits by United Kingdom workers to the dominions and colonies are equally essential. Some aspects of agricultural research are more advanced in other parts of the Empire than in the United Kingdom and the interchange of visits should be mutual. Consideration might also be given to holding specialist conferences in the dominions from time to time as a means of facilitating such visits, e.g. a soils or grassland conference might well be held in New Zealand.

Permanent interchange of scientific personnel would be facilitated if some arrangements could be made for transfer of superannuation benefits from one country to another. This applies more particularly to senior officers with a number of years' superannuation contributions.

SCIENTIFIC LIAISON SERVICES

New Zealand established a regular scientific liaison service in the United Kingdom with the appointment of Mr. Nevill Wright as Scientific Liaison Officer in London in 1928. The further development of such services was curtailed by the economic depression after 1929 and it was not till 1937 that an assistant Scientific Liaison Officer was appointed to London. To facilitate exchange of information under war-time conditions a New Zealand scientific liaison officer was appointed to Melbourne in 1943 and one to Washington in 1944.

The purpose of the New Zealand Scientific Liaison Office in London was to maintain closer touch with scientific developments in the United Kingdom and to facilitate exchange of scientific information between the two countries by :—

(*a*) Answering specific inquiries from New Zealand, D.S.I.R. or other government departments.

(*b*) Forwarding advance information on work in progress in the United Kingdom. Information was often made available many months before publication.

(*c*) Arranging and often assisting in the examination of shipments of

New Zealand produce under experimental conditions—often in collaboration with officers of F.I.B.

(*d*) Arranging for reports on new or improved products from New Zealand such as agar, bentonite, phormium, linen flax, medicinal plants, etc.

(*e*) Representing New Zealand Government on various scientific committees, e.g. F.I.B., I.A.B., Imperial Institute, etc.

(*f*) Acting as New Zealand representative at scientific conferences when specialist representatives from New Zealand are not able to be present.

(*g*) Arranging itineraries and effecting introductions, etc., for specialist New Zealand officers visiting the United Kingdom.

(*h*) Keeping United Kingdom workers informed of research work in progress in New Zealand in their related fields, and where possible establishing direct contact between workers in the two countries.

(*i*) Acting on selection committees to interview applicants for scientific posts in New Zealand.

(*j*) Obtaining supplies of new or improved crop or pasture seeds at an early stage of increase for trial under New Zealand conditions and providing supplies of New Zealand seed for trial in the United Kingdom.

(*k*) Answering requests from United Kingdom inquirers for information of a scientific or technical nature about New Zealand.

(*l*) Advising New Zealand purchasing officers about the purchase of scientific equipment for government departments (especially in war-time when substitution is often necessary and communication slow and uncertain).

The variety of subjects over which inquiries have ranged is illustrated by the brief titles of the main reports furnished to New Zealand by the Scientific Liaison Officer, London, in the first six months of 1938—see Appendix II. These covered fifty-six subjects, many involving more than one report. It is estimated that in 60 per cent of these inquiries knowledge of local New Zealand conditions was necessary or desirable ; the remaining 40 per cent of inquiries related to processes or methods requiring no local knowledge.

In the remainder of the activities a knowledge of local New Zealand conditions might be regarded as virtually essential. A great deal of the value of such reports and inquiries, particularly in the agricultural field, would be lost if inquiries were not pursued and reports written against a background of New Zealand conditions and requirements. Ideally, a liaison officer should know every senior research worker in the Dominion and his main line of approach to his problems. His knowledge should be maintained up to date by at least triennial visits to New Zealand of say six months' duration, a constant flow of reports from New Zealand and visits by specialist workers serving to maintain contact in the intervals.

In any British Commonwealth liaison service in London I would therefore regard it as essential that any New Zealand group participating should be led by a fairly senior scientific officer of wide interests who

would regard scientific liaison as a permanent job. He would need assistance by junior officers undergoing training or by specialist officers seconded to him for shorter periods. There is a grave danger, however, in over-centralizing or over-organizing liaison contacts. Our liaison in the past has been essentially personal in character and the excellent results obtained have in no small measure been a product of the high personal regard in which our officers have been held. Careful selection and training of officers and relative permanency in their appointments are more or less essential to the type of liaison service New Zealand has maintained in London. Senior posts in the liaison service should be of sufficient status to attract and retain men of adequate calibre and attainments.

Consideration of peace-time liaison requirements should not be based too largely on war-time experience. Inquiries on defence or food matters under war conditions were probably of wider applicability than will prove to be the case in peace-time and the scope for joint inquiries may be much restricted. Our experience in peace-time London was that where say Australia and ourselves were interested in a common subject, overlapping in inquiries was avoidable by joint visits, or in the case of less important visits by exchange of reports. Contact with the Canadian Agricultural attaché and Australian officers was maintained by lunching together at frequent intervals, by joint visits, at meetings, etc. The advantages of a centralized office for all scientific liaison officers may easily be more than outweighed by the disadvantages of separation from the respective High Commissioner's offices unless the central office can be found accommodation somewhere in the Strand or its immediate vicinity. The advantages of the scientific liaison officers being situated in their respective High Commissioner's offices are direct and concrete ; the advantages of a centralized office *in peace-time* may prove less real than imagined from war-time experience.

APPENDIX I

LIST OF NEW ZEALAND SCIENTIFIC WORKERS KNOWN TO BE IN THE UNITED KINGDOM OR UNITED STATES OF AMERICA IN THE PERIOD 1936–1939 INCLUSIVE

(*a*) *Students pursuing post-graduate study*

Dr P. R. McMahon—University of Leeds
M. M. Cooper—Univeristy of Oxford
Dr I. E. Coop—Universities of Oxford and Cambridge

In addition, there must have been a considerable number of students in pure science and medicine of whose names I am unaware.

(*b*) *Officers of research departments pursuing further study*

Dr C. P. McMeekan—University of Cambridge
Mr L. W. Tiller—Low Temperature Research Station
Dr Shorland—University of Liverpool
Dr Davies—Macaulay Institute for Soil Research
Dr Gibbs—Minnesota
Miss Kidson—Rothamsted

Dr Reid—University of Edinburgh
Dr Barnicoat
Dr Simmers—M.I.T.
Dr I. L. Campbell—University of Missouri

(c) *Visitors to New Zealand*

Dr A. J. Smith and party (1937)—Cambridge Low Temperature Research Station
Australian delegates to Auckland meeting of Australian and New Zealand A.A.Sc. (1937)
Dr Hammond—University of Cambridge School of Agriculture
Professor J. H. Kolb—University of Wisconsin
Dr Crystal—Imperial Forestry Institute
Dr G. J. Hucker—New York State Agricultural Experimental Station
Dr H. H. Mann—Woburn
Professor Findlay—Aberdeen
Professor Wilson—University of California
Dr A. J. Smith (1939)

(d) *Visits by specialist officers to United States of America or United Kingdom*

R. Calder	G. Holford	Dr Marsden
Mr Cockayne	Dr Hopkirk	Mr Muggeridge
Professor Denham	E. Hullett	Dr Oliver
Dr Frankel	Mr James	Professor Riddet
Mr K. Griffen	Mr Kissling	Mr P. White
Mr Hadfield	E. Bruce Levy	Dr Whitehead

APPENDIX II

Queries and information requested from Liaison Office, 1938 (1st January–30th June)

Mechanical methods of extraction of essential oils from citrus
Commercial gas storage trials, Cox's Orange Pippins
Elgin gas storage process
Report on Kirdford fruit juice plant
Report on Schoop process for fruit juice
Dietetic value of apple juice
Report on Orchard Products Ltd. plant at Wisbech
Descriptions and costs of pulp washers, bottling tanks, etc.
Spreadability of butter—methods of determining
Wrapping materials for butter—search for new or improved types
Anti-oxidents for butter fat
Disposal of dairy effluents
Sources of cobalt slag
Radioactivity and its possible relation to goitre
Shipments of parasites from Farnham Royal
Details *re* potato expedition to the Andes
Forwarding of grass-seeds required

Selection and arrangements for appointment of W.M.R. Director
Fireproofing of timber-methods in use
Fischer Tropsch process
Report on baconer carcasses, trial shipment *ex* New Zealand
Arrangements for report on New Zealand bentonite
Samples of glauconite for water-softening forwarded
Inquiries and reports *re* linen flax
Inquiries and reports *re* phormium
Inquiries and reports *re* phormium pulp and Pomilio process
Inquiries and reports *re* Italian hemp cultivation
Arranging and reporting trials with experimental lots of pelts
Methods of measuring riding comfort in railways
Arranging membership of W.M.R.A. Torriden for New Zealand W.M.R.A.
Reports on various aspects of kauri gum purification, etc.
Attended Oxford Farming Conference
Manufacture of asbestos wallboard
Clorinated rubber paints
Reports on cocksfoot midge
Reports on two port loadings of pears in one hold in New Zealand
Extraction of crude pectin for jam-making
Matzka process for unfermented apple juice
Progeny recording scheme for bulls
Pitting of tinned-steel cream cans—possible use of anodized aluminium
Report on preliminary tests of ' Styroflex ' as wrap on butter
Report on ' plastic cream '
Nutritive value of butter and margarine—suggested programme of research
Casein for lanital manyfacture—arranging preparation of special trial lots from New Zealand
Plant hormones
Collection of specifications for motor fuels
Drying of grass seed and arranging tests
Arranging membership United Kingdom Boot and Shoe Research Association
Soil samples of known radioactivity forwarded
Arranging selection and appointment of Wool Metrologist
Pressure impregnating plant for timber preservatives
Use of 16 mm. cine films for instructional purposes
Copies of numerous local authorities' building by-laws
Arranging despatch Janert drainage meters
Air-conditioning plants—costs, specifications, etc.
Attended International Wool Conference

ACADEMIC CO-OPERATION IN THE BRITISH EMPIRE

By Dr W. B. Mann
Imperial College of Science and Technology, London, S.W.7.

The purpose of the Royal Society Empire Scientific Conference is, presumably, to consolidate, at least in the scientific field, the bonds which have been wrought by the impact of six dangerous years of war, years which have called forth a unity of sacrifice and endeavour unprecedented in the history of the British Commonwealth. During this period scientific men, amongst others, from all parts of the Commonwealth have been brought into closer touch with each other than ever before ; the incentive now is to maintain this contact and to carry over a war-time necessity into the years of peace. Under the stress of war it has been recognized that no amount of documentary exchange can successfully be substituted for the many and varied aspects of personal contacts ; the liaison and co-operation which has been developed to meet our military needs can be expanded so that in the years ahead the Commonwealth shall achieve a position of moral influence and prestige which shall be second to that of no other nation or group of nations.

In this discussion it is our purpose to consider the rôle of university or academic co-operation within the wider framework of Commonwealth scientific collaboration. That such co-operation in teaching and research will be of far-reaching importance can scarcely be gainsaid, for university men and women occupy positions of considerable influence both in their universities and colleges as teachers and also in the world throughout which they become dispersed in industry, in government and in kindred non-academic occupations. A man who has undertaken teaching or research in another Dominion is a living and continuous link between his friends and colleagues there and those at home. Abroad he is a symbol, transient maybe, of academic life and scientific method in his own country, while, on his return to his native land, he is the interpreter of the academic life and scientific method which he has learnt to know away from home. He has become, moreover, a focal point ; a person to whom his colleagues from home and overseas will come for introductions in, and information about, either country.

The last decade has witnessed a fundamental change in the accessibility of all parts of the Commonwealth ; no capital city of any Dominion can now be considered to be remote from another or from London. Financial considerations apart, the present-day student can contemplate flying from the United Kingdom to Canada with as much equanimity as he would taking a journey from the south of England to Edinburgh or to Aberdeen.

Academic co-operation can also become effective both by encouraging the pooling of resources and the exchange of information, as well as by promoting the movement of university and college staff and students between the centres of learning and research within the Commonwealth. The dissemination of scientific information has, in the past, been quite effectively undertaken by the journals and publications of the various learned societies ; the increased output of research threatens, however, to increase the demands on these accepted media of publication and new and expanded facilities may well have to be provided. The procuring of more detailed information, such as drawings of equipment and so forth, can be effected either by personal correspondence or through the agency of a Commonwealth Scientific Liaison Office operating either in the United Kingdom or in the Dominion in question. The pooling of resources is an aspect of the general problem of scientific co-operation which is more likely to arise on the governmental than the scientific plane. Certain equipment, such as supersonic wind-tunnels, may exist only in this country and could be made available to the competent authorities in the Dominions, whereas, in other respects, the special facilities in any one of the Dominions may make it desirable to carry out experiments there rather than to duplicate costly equipment or to reproduce certain conditions elsewhere. Future projects of a costly nature might well be co-operative ventures located in a particular university or research laboratory in the Commonwealth, the location to be chosen from considerations of availability of raw materials, specialized personnel and so forth. Such joint undertakings would, however, be equally available to all specialists or research and government departments of any country of the Commonwealth. It is the last category, the interchange of personnel, which probably offers the greatest opportunity for strengthening the ties and increasing the co-operation and understanding between the universities and scientific institutions of the Commonwealth.

In all these aspects the co-operation envisaged will be facilitated by the establishment, in each Dominion and in the United Kingdom, of a Commonwealth Scientific Liaison Office of the kind already functioning in the United States, namely the British Commonwealth Scientific Office, but with terms of reference which shall be extended to cover non-governmental scientific liaison in addition to liaison of an official or service nature. These Commonwealth Scientific Liaison Offices should be in a position to advise on the university facilities available in each country of the Commonwealth and could also help in making the necessary arrangements for the reception of a scientist who wished to spend some time at a university or research institution in some other part of the Commonwealth. Such an office can also render inestimable service in procuring, either by purchase or as a loan or gift, special equipment or specimens such as, for example, rare or indigenous biological materials. University research staff might also be attached to the Liaison Office for short terms of duty for the purpose of paying visits, in connexion with their own specialities, to the various centres of research or production specializing in the subject in question. The policy and staffing of the U.K. missions to such offices will probably be under the control of an inter-departmental committee and therefore, if the Liaison Offices are to assume

these wider responsibilities of a non-government or non-official nature, it will probably be desirable to obtain representation of the learned societies and universities on this committee.

The opportunities for university personnel to travel to British Commonwealth universities and research laboratories overseas can be summarized as follows :

1. Teaching staff
   (*a*) visiting lectureships
   (*b*) sabbatical leave
   (*c*) interchange of staff
   (*d*) seconding of staff.

2. Postgraduate research students :
   (*a*) travelling fellowship or research scholarship
   (*b*) junior demonstratorship.

3. Undergraduate students :
   (*a*) complete undergraduate courses in any Commonwealth university abroad
   (*b*) penultimate year or last two years abroad
   (*c*) summer vacation ' works ' experience.

In the case of teaching staff it would be generally true to say that the more senior the man the less time he has to spare for prolonged visits abroad. In spite of the undoubted value of such a visit, his time is fully occupied by administering his department or by directing research ; his teaching duties can, however, often be spread over the rest of the staff. On the domestic side his children may have reached such an age as to make one or two years' interruption of their education undesirable and so, if he went abroad, he would have to leave his family behind. Much of the value of a long-term visit is then lost, for the social contacts are also of some importance. To provide for such senior men of eminence a system of visiting lectureships would be of inestimable value ; of value to them as a means of maintaining contact with the scientific leaders in other countries of the Commonwealth, and also of value to the students in those countries in that they are given the opportunity of hearing, first-hand, an outstanding man of science talking about a field of endeavour with which he has been intimately concerned.

The Nuffield Foundation proposes to make grants to assist such senior men to pay lecturing visits to other parts of the Commonwealth and states that, as such eminent men are also busy men, such grants will take account of the cost of travel by air, so that the maximum benefit, both in length and frequency, may be derived from such visits. The use of air transport will enable these visits abroad to be made during periods of leave or in the course of a university vacation. In this connexion it is to be noted that the universities in the southern hemisphere are in full session during the time corresponding to the long vacation in this country and in Canada. There is, therefore, every opportunity for making lecture tours in that hemisphere in the months from June to September.

For some time it has been customary for universities in the United States

to maintain funds for the purpose of inviting distinguished men and women from abroad as guest lecturers. I am unaware of any widespread tendency in this direction in British universities and can only refer to the Guest Research Fund of the Bernard Price Institute of Geophysical Research at the University of the Witwatersrand and to a similar fund administered by the Academic Council of the University of London. The former fund is designed to meet the expenses involved by a short visit to the Institute by an overseas scientist of distinction, approximately £150 being available every two years. Due to the intervention of the war it has been possible to have only one guest ; this was Dr E. Bullard who spent about three months at the Institute. It is stated that visits of this particular type are regarded as being of special value. In the case of the University of London, before 1939, a sum of £1,400 was allocated for lectures by distinguished scholars not connected with the University. The scheme has been partially resumed in the session 1945–1946, and lectures have been given by scholars from America, France, Switzerland and Holland. In the session 1946–1947, it is expected that a grant of £2,500 will be available for these lectures, and in future years it is hoped that the sum will be considerably increased.

Such lecturing visits of relatively short duration, but repeated at as frequent intervals as administrative exigencies and financial considerations will allow, would appear to be best suited to meeting the requirements both for and of senior members of staff. Visits of longer duration, however, are likely to be of greatest value, from the point of view of guest and host alike, in the case of men of medium seniority who, while active in research, are not yet too heavily burdened by administrative duties ; for such men the opportunities for working abroad are, perhaps, at present too few.

Some universities in the United Kingdom recognize the value of sabbatical leave and are willing to maintain the pension rights of staff who wish to go abroad for teaching or research for periods varying from two months to one year. Not all of these, however, are able to pay more than a fixed proportion of the salary of the absent member of staff. The University of Cambridge, for example, makes provision under University Statute DX 115 for such sabbatical leave. This statute entitles every university teaching officer to one month's leave of absence for every six terms of completed service provided that no account be taken of any service done by such an officer more than six years before. It is stated, however, that difficulties arise in that it is not always possible for a teacher to obtain release from college commitments at the same time as the university is prepared to release him. Examination and casual teaching fees must be sacrificed and a married teacher may be reluctant to travel without his family and unable to travel with them if his only financial support is the maintenance of his university and college pensionable stipends.

In South Africa sabbatical leave is, in general, granted every six years. While there is some variation from university to university it is usual to give three months leave on full pay and three months on half-pay ; a further period of leave without pay may occasionally be granted. Information regarding the maintenance of pension rights is not available at the time of writing.

The interchange of teaching staff is a method of gaining overseas experience which has been practised with varying degrees of success. One's job, home, car, and, possibly, salary are exchanged for a year or more with those of a colleague in an overseas teaching or research institution. The success of such an arrangement depends very largely on a number of factors, both professional and personal. It has been stated for example, that it is wiser to limit the interchange to academic duties and to make domestic arrangements abroad independently of one's colleague whose mantle, in other respects, one is temporarily assuming. On the professional side there may be difficulties in fitting-in with a different programme of teaching courses and it is almost certain that the first year will be spent largely in modelling one's lectures to the new surroundings. Such an interchange of staff can only really bear fruit in the second year when one's teaching will carry on to some extent under the momentum acquired in the first year and there will be time available for research, colloquia, and the round of social duties. So many such interchanges are, however, limited to one year and, for such a period, are of somewhat doubtful value. For periods of a year or less sabbaticals and visiting lectureships are probably more profitable. In the case of the former there is no teaching while in the latter a course of lectures is given which is outside the curriculum.

Recently the Imperial College of Science and Technology has concluded an 'alliance' with the Massachusetts Institute of Technology. The terms of this alliance provide for the interchange of teaching staff and students and it is understood that further such arrangements between individual United Kingdom and United States universities are envisaged. Apart from a similar alliance between the Imperial College and the Indian Institute of Science, Bangalore, no such arrangement between United Kingdom and Dominion universities, nor between the universities of the different Dominions, has yet been reported.

The interchange of teachers from secondary, primary and nursery schools, as well as from the training and technical colleges in this country, with those from other countries in the Commonwealth is already undertaken on an appreciable scale by the League of Empire. The English-Speaking Union arranges for the interchange of teachers between the secondary, primary and nursery schools of the United Kingdom and the United States of America. The League of Empire is also trying to promote inter-Dominion exchange of teachers.

The Nuffield Foundation, in addition to the scheme for promoting lecturing visits, is also interested in the question of interchanging and seconding academic staff between, and seconding them to, the teaching institutions of the Commonwealth. The Foundation considers that the value of schemes designed to promote such movements of staff is undoubted but also feels that such arrangements might be extended beyond the Dominions and Colonies and to persons other than those on the academic staff of universities and teaching institutions. It is proposed to carry out a survey of the position in various parts of the Commonwealth and it is hoped to assess the extent to which such interchange schemes may require the financial support of such bodies as the Foundation. The Foundation proposes that this survey should aim at compiling as full information as

possible regarding existing awards and should also gather authoritative opinion regarding unsatisfied needs. Information will also be sought regarding the facilities existing in the Dominions for postgraduate study. Answers to many of these questions can and, probably, will be supplied by the delegates to this conference. The provision of other information of this kind could well be a task for the projected Commonwealth Scientific Liaison Offices. Financial support to the various schemes for interchanging and seconding staff would probably be welcome in the form of grants for the purpose of defraying travelling expenses. In this connexion the reductions in fares made by certain steamship lines to university men and women travelling abroad from this country and the Dominions, for purposes of study, are to be noted ; it is to be hoped that these concessions will both be maintained and also extended to include travel by air and rail. Fellows of the Royal Society of Canada are allowed free rail travel in Canada to attend the annual meetings of the Society. It would appear that this concession is equivalent to a subsidy for travel made by the Canadian Government.

It is in the field of postgraduate research that probably more adequate provision has been made for overseas travel than in any other. A summary is given, in an Appendix, of travelling fellowships and scholarships available either to United Kingdom or Dominion students. Many of these, it is true, are equally available to junior, even senior, members of university teaching staffs. The list of such scholarships appended has been compiled from a number of pre-war and post-war sources and every effort has been made to ensure its accuracy. The present time, however, is one of flux and change and it is almost assuredly already out of date. It will serve, however, to indicate the facilities available to research students for overseas study and will indicate any marked tendencies as, for example, that many more opportunities are available for Dominion students to come to the United Kingdom than *vice versa* or for Dominion students to go to other Dominions. Such travelling fellowships and scholarships as are available to United Kingdom graduates for study abroad are often too meagre to allow even a trans-Atlantic return trip let alone to envisage a journey to, say, Australia and back ; they have, in fact, often been instituted with nothing more in mind than a year at a German university, or at Copenhagen, or some other teaching institution of note within easy reach on the continent of Europe. For this purpose they have been entirely and admirably adequate. For the purposes of Commonwealth travel, however, it will be necessary to provide funds to meet travelling expenses. *In most cases such a supplement to a scholarship will be all that is required to make it available for tenure in any part of the Commonwealth.* The institution of some special fund from which such supplementary travel grants can be awarded should be a stimulus to inter-Commonwealth visits.

It is possible that, in some universities, ordinary postgraduate research scholarships can be held abroad, at least for a part of their term. This is apparently so in the case of studentships awarded by the University of London where the 1946–1947 budget for such studentships is more than four times as great as the sum expended in 1938–1939 ; some £18,000 as compared with £4,000 pre-war. Two types of studentships are being offered, one type being awarded on the result of the London final examina-

tions while the other is open to graduates of the University in any faculty. The former type will consist of awards of not less than £200 and the latter of not less than £250; each is for one year's duration. All subjects other than clinical medicine are included and the scholarships are quite distinct from, and in addition to, any awarded by the schools of the University. While there is no ruling in the statutes against these studentships being held outside London such a procedure would be unusual during the first year of tenure. It is conceivable, however, that a second year abroad would be sanctioned in the case of a student applying for an open scholarship after having held a studentship of the first type for one year in London. In such a case it might be necessary to make a supplementary grant to meet travelling expenses. Such a grant could possibly be made from the new £2,000 per annum fund for travelling studentships which has been instituted to replace the two pre-war University Travelling Studentships of £275 each.

A Central Research Fund of £8,000 per annum is also maintained by the University of London to help research workers by grants for equipment or to defray travelling expenses. Such awards are, in the case of this fund, available only to members of the University but assistance from the fund is available to such members irrespective of whether or not they are currently working at the University; an applicant might, for example, be a schoolteacher seeking financial assistance for a short trip abroad for purposes of study.

There is a marked preponderance in the flow of students from the Dominions to the United Kingdom over that in the opposite direction while that from Dominion to Dominion is also small. What, therefore, can be done to stimulate a flow outward from this country and also from one Dominion to another? The provision of adequate financial support is a necessary but not a sole consideration. Academic prestige and research facilities are equally important. A physics student given £150 plus travelling expenses with freedom of choice as to tenure is as free to go to Copenhagen as to, say, Cambridge or Montreal. His ultimate choice will be conditioned as much by the current prestige and standing of the department as by considerations of local topography, of historical or traditional background, or of just seeing the world. It is therefore incumbent upon all of us, who have this ideal of closer co-operation at heart, to strive to attain in our own country, our own university, and our own department in the university, the best possible in scientific research facilities and, above all, in scientific thought and leadership. A system of scholarships to attract students overseas is not enough; the prestige of our universities must at least be equal to, if not higher than, those of the great centres of learning and research which lie outside the territories of the British Commonwealth. Only thus can we hope to retain good men and to attract new blood to infuse into the old.

A recently graduated student will probably not be wholly averse to combining a small amount of teaching with his research work abroad. It is not, therefore, necessary to confine our attention only to the provision of research and travelling fellowships for graduates. Generally the most junior teaching appointments are ear-marked for internal graduates of the university desiring to proceed to a Master's or Doctor's degree. It is not inconceivable, however, that a very small proportion of such appointments

could occasionally be offered to outstanding graduates from other countries in the Commonwealth. The offering of such appointments and the choice of a suitable candidate could readily be left to the appropriate Dominion or United Kingdom representative in the Commonwealth Scientific Liaison Office in the country in question. Once again travelling expenses would have to be defrayed by a special grant. As a result of such appointments many promising young graduates may be given the opportunity of promotion to the permanent staff of the university which they are visiting and may constitute a welcome and valuable source of new blood and fresh ideas. Those students who return, however, after one or two years abroad will probably wish to submit their work for a higher degree. It may therefore be necessary for universities to revise their regulations for higher degrees in order to admit, as a whole or partial contribution, work done at approved Commonwealth universities. The achievement of recognition in a general system of approved universities will be an incentive to departments to maintain an appropriately high standard of research and advanced study.

It has been suggested that the Appendix, expanded to include full information as to when and to whom application should be made, should be issued in booklet form and given wide distribution amongst the universities of the Commonwealth. In this way it might act as a stimulus to applications from overseas scholarships.

The aspect of any scheme for overseas visits which is likely to present most difficulty is that concerned with undergraduate students. Each university has its own peculiar methods of teaching and examining, and the programme of courses is often left to the individual departments. The course, say, in electromagnetic theory may be given in a specified year at one university ; another may allow students to choose which courses they will take in any one year. In some cases, too, a student may take part of his final examination at the end of the year preceding his final year. It is not, therefore, easy for an undergraduate student to move from one university to another at will. Adoption of a credit system similar to that operating in the United States would make such movement possible, but to institute such a system for the universities of the Commonwealth would in itself be a task of considerable magnitude. The primary consideration in the minds of undergraduates is, naturally, to obtain a degree. Having settled down to the routine, therefore, of the university or college of their choice it is unlikely that they will choose to uproot themselves for a year or so to travel overseas simply to study at a department which has a reputation in a certain field or to learn from a teacher who is a great exponent or authority. The student will rather be prepared to acquire that information from his own lecturers or the published literature. Such sitting at the feet of men of eminence can probably best be left, at least in the light of the more materialistic needs of to-day, to the immediate postgraduate years.

An arrangement which does not give rise to the difficulties referred to in the preceding paragraph would be one whereby facilities could be provided for young men and women of university age to go to a university overseas for the whole of their undergraduate courses. Such a scheme would call for an extension of the present system of government bursaries,

available to students in this country, so as to make them tenable overseas. Many scholarships and grants from local councils might likewise be extended in scope. At a time when the authorities in this country are seeking to expand the facilities for higher education, the possibility of transferring students to Commonwealth universities where the necessary extra capacity may already be available and maintaining them there may well be worthy of consideration. It is, however, not unlikely that such extra teaching capacity may not now, in fact, be available in any part of the Commonwealth to permit of the institution of such an Empire 'training scheme.' Such a system however, designed primarily to relieve congestion in this country, might well give place eventually to bilateral arrangements for the interchange of undergraduate students.

An academic practice which finds favour, to a limited extent, in the United States is that of spending the 'junior year' abroad. The student travels, say, to Europe during his penultimate undergraduate year and there takes courses on subjects which are requirements for the examinations to be taken at the end of the final year at his prospective *alma mater*. Such a system could be practised by students at Commonwealth universities which did not hold half-yearly, or even yearly, examinations. The question of a common inter-university standard does not arise since no examinations are taken or credits awarded at the university abroad. It is left to the student to acquire such knowledge in a certain limited number of subjects as will enable him to qualify in these subjects in his final examination on his return home. Such a sojourn abroad may be of great value in the strengthening of character and self-reliance ; but only few students might be willing to break the many ties and associations, academic, social, and athletic, at that stage in their undergraduate career.

The summer vacation, during undergraduate years, probably presents the best opportunity for trips abroad. During this vacation many students of technological subjects endeavour to obtain field work or industrial works experience. In certain subjects, as, for example, mining or forestry, such experience might best be gained overseas. The difficulties inherent in the organization of such short-term visits abroad are likely to preclude their extension to Commonwealth countries except in the case of a few individuals. Indeed any attempt to *organize* summer-vacation visits to the Commonwealth might savour too much of travel for the sake of travel rather than of gaining industrial experience. At the present time the Imperial College Union is making arrangements for students of electrical, mechanical, chemical and civil engineering and of chemistry to visit Belgium, Holland, Norway, Sweden and Switzerland for six weeks in the coming summer to obtain experience. Arrangements have also been made for two students of mechanical engineering from the College to make the trip to Abadan and back on one of the oil-tankers of the Anglo-American Oil Company. While mechanical engineers can well obtain experience on, say, trans-Atlantic liners and freighters it is unlikely that there will be any great demand from students desiring to obtain experience by visiting industrial undertakings in Commonwealth countries overseas. In the summer of 1945, however, one student spent nine weeks with the International Nickel Company in Ontario. Valuable experience was gained but such trips are likely to remain the exceptions rather than the rule on

account of prohibitive travelling expenses. It may be felt that there is reason to suggest the institution of some fund designed to assist in such individual cases. On the other hand the cause of Commonwealth collaboration is not likely to be best served by short-term visits of this kind which are primarily to gain experience but in which, however, the more indefinable personal contacts and social activities must of necessity be somewhat neglected. The emphasis in such a visit is upon the acquiring of knowledge about methods and equipment rather than about people and the way they live. The more mature postgraduate student is probably better suited to achieving a proper balance between these two aspects of his sojourn abroad.

The present-day financial restrictions present a quite serious obstacle to any scheme for overseas visits, be it for university teaching staff or students. It has been suggested that national scientific societies, e.g., the Royal Society, the Royal Society of Canada and so forth, might act as clearing houses in this matter. The Commonwealth Scientific Liaison Offices, when established, might also function in this capacity. A scientist from the United Kingdom visiting, say Canada, would, under such a scheme, then be able to draw dollars in Ottawa which would be balanced against corresponding sterling withdrawals by Canadians in London. In seeking Treasury approval for such a scheme a statement of Treasury policy should also be sought regarding the extent to which financial approval would be given to travel from this country. Moreover the position is far from clear regarding the award of scholarships founded and administered in this country which normally would be open to, say, a New Zealand or Australian student and which before the war would be tenable in Canada. Will permission for the necessary dollar transfer be forthcoming? Such a situation could, for example, arise from the award of an 1851 scholarship; these are open to students from the Dominions and are tenable anywhere outside their native land.

The foregoing discussion has been mainly concerned with the fostering of relatively short-term overseas visits by staff and students from the universities and colleges of the Commonwealth. However, in the period of post-war technical reconstruction and expansion, there is likely to be a considerable demand throughout the Commonwealth for qualified scientists and technologists on a more permanent basis. This demand could possibly be partially met from the resources of the United Kingdom; there are indeed many young men and women graduates in science and technology who desire the opportunity to emigrate to some other part of the Commonwealth. It is understood, however, that the Ministry of Labour in this country has only an incomplete picture regarding such Commonwealth needs. The provision of such information for incorporation in the Technical and Scientific Register of this Ministry should be regarded as a matter of urgency by the competent authorities in those parts of the Commonwealth where a shortage of technical man-power exists. But it must be borne in mind, however, that if the transfer of our technical personnel overseas assumed large proportions, it would, of course, create difficulties for industry in Great Britain.*

* Estimated requirements for scientific workers in the United Kingdom and Colonial service are given in the report of the Committee on Scientific Man-power (H.M. Stationery Office, Cmd. 6824).

The time is also long past when such a transfer of personnel can be counted this country's loss and, say, Canada's gain. International policy is now thought of in terms of world affairs and not in relation, say, to the continent of Europe, of Africa, or of Asia. No future conflict can be confined to such continental limits and peace is correspondingly a world concept. We have learned that our strength in war has lain in co-operation and mutual sacrifice ; our influence in peace, and for peace, can spring only from the same conceptions. Loss of some of the technical man-power from Britain to the Commonwealth overseas does not of necessity connote a weaker or poorer Britain ; it may imply a better-balanced use of our scientists and technologists *throuhgout* the Commonwealth and, therefore, a *stronger* Commonwealth whose moral influence in a rapidly shrinking world will be correspondingly enhanced. The time has come to think of the Commonwealth as a whole ; to organize and to use our scientific man-power for the greatest benefit of all.

A practical suggestion to this end is the extension of F.S.S.U. (the Federated Superannuation Scheme for Universities) to the whole Commonwealth. Such an extension would do much to encourage teaching and research staff to take jobs abroad and to stimulate a flow in both directions. As reported by the Barlow Committee,* F.S.S.U. is to be made available to almost all scientific officers in the permanent service of the Government in the United Kingsom so that there may be no barrier on account of pension arrangements to the interchange of scientific staff in the government departments and the universities. The extension of F.S.S.U. to the Commonwealth would make such interchanges possible between, say, C.S.I.R. in Australia and a university in the United Kingdom.

In the field of medicine the question may also arise as to the desirability of establishing recognized qualifications that would enable doctors to practise in any part of the Commonwealth and to encourage medical men to move at will from any part of the Commonwealth to another. Such a uniformity of recognition is at present lacking ; I understand, for example, that three provinces in the Dominion of Canada recognize United Kingdom qualifications while the rest do not. Such a lack of uniformity may also exist in other professional fields such as dentistry, veterinary service, engineering and so forth.

In considering this question of the scientific man-power for the Commonwealth as a whole, my attention has been drawn to the special conditions existing in Canada where a number of research workers are attracted to the United States by scholarships which are available to U.S. and Canadian citizens. A high proportion of these scientists ultimately remain in the United States, thus making even more acute the shortage of scientists in their own country. This problem would appear to emphasize the point which has already been made, that it is incumbent on us to see that the opportunities within the Commonwealth are as attractive as those existing elsewhere.

The field of Commonwealth academic co-operation is one in which much yet remains to be done. It is unlikely that the discussion by the delegates to this conference will cover more than the essentials of general policy. There will, almost assuredly, be scope for the appointment of a

* H.M. Stationery Office, Cmd. 6679.

small group or committee to discuss detailed ways and means for fostering such co-operation and to consider the requisite machinery for achieving it. Such a committee would have to get in touch with the University authorities throughout the Commonwealth to ascertain and collate their views on the feasibility of the various schemes previously referred to under the headings 1 (*a*) to 3(*c*) ; and, in this connexion, to consider the possibility of obtaining funds from which grants can be made for the purpose of defraying travelling expenses, either partially or in whole, thereby supplementing existing scholarships and increasing their range of tenure to more remote localities. It would need to discuss with the scientific authorities in the Dominions their probable requirements for scientific and technological man-power, the extension of F.S.S.U., and also the question of how scientific co-operation could be assisted by the speedy formation of Commonwealth Scientific Liaison Offices. Problems arising from current financial restrictions and the question of arranging for funds or for clearing-house facilities for approved visits should be considered.

In preparing this brief paper I have to acknowledge with thanks the help which I have derived from discussions with many friends and colleagues.

ACADEMIC CO-OPERATION IN THE BRITISH EMPIRE

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Note—This appendix is reprinted with only a few corrections and additions and is substantially the same as the one presented at the time of the Conference.

APPENDIX

In the appended list of travelling fellowships and scholarships every effort has been made to ensure the accuracy of the information given. Draft lists have been circulated to all universities and institutions referred to in the U.K. section, while the help of the Dominion Liaison Offices has been sought in obtaining information and amendments for the other sections. University calendars up to the year 1944 have also been consulted. Due to the extremely short time available, however, this list must be regarded as being tentative and far from complete. If a comprehensive list along these lines is regarded as being desirable, this present one might be given a far wider circulation throughout the Commonwealth and appropriate corrections and amendments invited.

The scholarships and fellowships have been classified (column 4) as follows :

(U.K.) Scholarships and fellowships open to students and research workers in the Dominions, India and the Colonies which are tenable *only* in the United Kingdom.

(Dom.) Scholarships and fellowships open to students and research workers in the United Kingdom which are tenable either *in a Dominion* or *abroad* being, in the latter case, available for tenure in a Dominion or Colony.

(D.–D.) Scholarships and fellowships open to students and research workers in the Dominions, India and the Colonies and tenable either in the United Kingdom or *any other part* of the Commonwealth.

Scholarships open only to men are marked (†), those open only to women (*).

In compiling this appendix I have to acknowledge the information I have derived from the ' List of International Fellowships for Research,' published by the International Federation of University Women, and the ' List of whole-time awards for scientific research, other than professorships, offered by public and private bodies in Great Britain and Northern Ireland,' published by the Royal Commission for the Exhibition of 1851.

LIST OF TRAVELLING FELLOWSHIPS AND SCHOLARSHIPS

UNITED KINGDOM

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ABERDEEN, UNIVERSITY OF							
Anderson Scholarship	Medicine	1st or 2nd year abroad	Dom.	2 years	£200 p.a.	Open to graduates in medicine of Aberdeen University, who must devote whole time to their research	The Secretary, University of Aberdeen
Robert Fletcher Scholarship	Mathematics or physics	An English or foreign university	,,	1–3 years	£75 p.a.	Restricted to graduates of not more than 2 years' standing who have taken the degree of M.A.	,,
Fullerton Moir and Gray Scholarships	Classics and other honours groups, *e.g.* English, history, mental philosophy, French, German, economics, etc.	,,	,,	2 years	£165 p.a.	Restricted to graduates in arts (M.A.) of less than 2 years' standing	,,
Fullerton Moir and Gray Scholarships	Mathematics and natural philosophy	,,	,,	,,	£185 p.a.	,,	,,
Kemsley Travelling Fellowship	Agriculture or forestry	Abroad	,,	1–2 years	£400	—	,,
Kilgour Scholarships (Senior)	Natural science	Special permission required to go abroad	,,	2 years	£150	Restricted to graduates in natural science or natural history	,,
Reid Scholarships	Literary or linguistic philology, philosophy, science, fine arts	An English or foreign university	,,	1 year (may be renewed)	Not stated	Restricted to distinguished graduates of Aberdeen University holding the degree of M.A. (Hons.), failing whom, holders of B.Sc. (Hons.)	,,
George Thompson Fellowship	Medicine	One year in Aberdeen and one year in other British or foreign university	,,	2 years	£200 p.a.	—	,,

Yuill Travelling Scholarship in Chemistry	Industrial and agricultural chemistry or chemical engineering	Unrestricted	"	1 year (may be renewed)	£150	Restricted to students of chemistry in the university who are Associates of the Institute of Chemistry or possess equivalent training	The Secretary, University of Aberdeen, by 1 March
Robbie Scholarship	Mathematics, natural philosophy or chemistry	At Aberdeen	U.K.	"	£300	Graduates of Aberdeen, if suitably qualified, are preferred. Holders to be adherents of a Protestant Church	The Secretary, University of Aberdeen
AGRICULTURE AND FISHERIES, MINISTRY OF, AND DEPARTMENT OF AGRICULTURE FOR SCOTLAND:							
Research Scholarships (limited number)	Husbandry, agricultural economics, and agricultural and dairy farming	At approved institutions at home or abroad	U.K., Dom., D.-D. (?)	Not more than 3 years	Not stated. Extra allowance if held abroad	Open to suitably qualified candidates. Scholarships in agricultural economics tenable in first place at British University with agricultural economics department. Those in agricultural engineering tenable normally for 2 years at National Institute of Agricultural Engineering. Those in dairy engineering in first place at National Institute for Research in dairying	The Secretary, Ministry of Agriculture and Fisheries, Block 4, Bickenhall Mansions, London, W.1, or the Secretary, Department of Agriculture for Scotland, St Andrew's House, Edinburgh, 1, before 15 July
AGRICULTURAL RESEARCH COUNCIL:							
Research Scholarships (15)	Agricultural science and animal health	At approved institutions at home and abroad	"	Not more than 3 years	£260 p.a. at Oxford and Cambridge; £250 p.a. at London; £220 elsewhere. Additional maintenance allowance for married scholars	Restricted to graduates of a British university with honours in science. They must be nominated by a professor or lecturer of a university or college or by the director of a research institute not later than 15 June	The Secretary, Agricultural Research Council, 6A Dean's Yard, London, S.W.1

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
Beit Memorial Fellowships for Medical Research:							
Junior Fellowships (6)	Medical research and allied sciences	Great Britain or in other places or countries specifically recognized for the purpose	U.K.	3 years (may be extended to 4)	£500 each p.a. (4th year, £600)	Open to candidates of any nationality holding a degree in any faculty in any university in the British Empire, or holders of a medical diploma registrable in the U.K. or associateship of a college approved by the trustees	Honorary Secretary, Beit Memorial Fellowships for Medical Research, Lister Institute, Chelsea Bridge Road, London, S.W.1
Senior Fellowships	"	"	"	3 years	£700 p.a.	Restricted to former holders of junior fellowships	"
Belfast, Queen's University:							
MacKay Wilson Travelling Scholarship	Medicine	Medical school or institution abroad	Dom.	1 year	£100	—	The Secretary, Queen's University, Belfast
Musgrave Research Studentships (3)	Pathology, chemistry and physiology; in alternate years pathology, biology and physics	Unrestricted	D.-D.	1 year (may be renewed)	£200 each	Open to British subjects, graduates of at least 1 year's standing in a university in the British Empire, and of marked capacity for original research	"
Purser Studentship	Mathematics	Any university approved by Academic Council	Dom.	1 year	£150	—	"
Haslett Browne Travelling Scholarship	Medicine, surgery, obstetrics or pathology	Abroad	"	"	£300	Open to graduates of Queen's University, Belfast	"
Leathern Travelling Scholarship	Medicine, surgery or obstetrics	"	"	"	£400	"	"
Birmingham, University of:							
Walter Myers Travelling Studentship	Any branch of pathology approved by the Selection Committee	An approved university or hospital not in Great Britain or Ireland	"	1 year	£300	Restricted to graduates in medicine and surgery of a British university who, for not less than 3 years immediately preceding the application, have studied in the Birmingham Medical School	The Dean of the Faculty of Medicine, The University, Edgbaston, Birmingham
Travelling Studentship	Research in pathology	Abroad	"	"	"	Awarded biennially	"

James Watt Research Fellowship in Mechanical Engineering	Mechanical engineering	University of Birmingham	U.K.	1 year (may be renewed)	£250	Open to Honours graduates of a British university	The Registrar, University of Birmingham
William Gibbins Research Fellowship	Research into copper, brass and non-ferrous alloys	"	"	2 years but may be renewed for one or more years	£250 p.a.	Open to graduates of a British university with preference to those having at least 1 year's research experience	"
Research Studentship in Oil Engineering and Refining	Oil engineering and refining	"	"	1 year renewable up to maximum tenure of 4 years	£240 p.a. with £20 p.a. increments on renewal	Open to students with a university degree, or the equivalence, in science, with preference to those having experience in an industrial laboratory	"
BRISTOL UNIVERSITY:							
Michael Hiatt Baker Scholarship	Unrestricted	University of Bristol	"	2 years but may be renewed for a third year	£200 p.a.	Awarded to graduates from New Zealand	The Registrar, University of Bristol
Arthur Prince Chattock Research Studentship	Physics	University of Bristol	"	2 years (may be renewed)	Not less than £200 p.a.	Open to graduates of any university but currently in abeyance	"
George A. Wills Research Associateship in Physics (3)	"	"	"	Variable	£300 p.a. or more according to qualifications of associate	Open to graduates of any university	"
BRITISH COUNCIL:							
Scholarships (25)	Education, economics, public health, social sciences, medicine, etc.	Great Britain	"	1 year	£300 plus travelling expenses to and from U.K.	Open to graduates from universities in the Overseas Dominions	The Secretary, British Council (representative in country concerned)
BRITISH FEDERATION OF UNIVERSITY WOMEN:							
Johnstone and Florence Stoney Studentship *	Biology, geology, meteorology or radiology	Australia, New Zealand or South Africa	Dom.	—	£250	Women graduates, or those with equivalent of degree, of U.K. university born in U.K. or of British Empire parentage. Holder to spend at least six months in Australia, New Zealand or South Africa within 18 months of award	The Secretary, British Federation of University Women, 17A King's Road, London, S.W. 3

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to
BRITISH FEDERATION OF UNIVERSITY WOMEN—*contd.* :							
Residential Scholarship •	Research unrestricted, or other post-graduate work	Crosby Hall, London	U.K.	1 academic year	£100	Open to graduates who are members of a national association of university women and who are nominated by their own association. In abeyance and conditions under review	The Secretary, British Federation of University Women, 17A Kings' Rd, London, S.W.3
BRITISH IRON AND STEEL RESEARCH ASSOCIATION	Metallurgical and physical sciences	Any approved institution	U.K., Dom., D.-D.	Variable	£200–£400 p.a.	Open to graduates of any university	The Director, British Iron and Steel Research Association
BUSK TRUSTEES :							
Busk Studentship in Aeronautics	Research in aeronautics particularly problems relating to stability and meteorology	Unrestricted	U.K., Dom.	1 year (may be renewed)	About £150	Open to British subjects other than of Asiatic or African descent	Professor Sir B. Melvill Jones, Engineering Laboratory, Cambridge
SIR JAMES CAIRD'S TRAVELLING SCHOLARSHIPS	Engineering, electricity, aeronautics, music	Unrestricted	Dom.	Duration not stated	Junior scholarships £50 to £250. Senior scholarships £200 to £600	Open to Scottish-born graduates or students	John Pearson, Esq., The Secretary, Sir James Caird's Travelling Scholarships Trust, 7 Ward Road, Dundee
CAMBRIDGE, UNIVERSITY OF :							
Balfour Studentship †	Biology	University of Cambridge	U.K.	3 years	£300 p.a.	Open to graduates of any university	The Registrar, University of Cambridge
Pinsent-Darwin Studentship	Mental pathology	University of Cambridge or with consent elsewhere	"	"	About £240	Open to graduates of any university	"
Gwynaeth Pretty Research Studentship	Pathology	University of Cambridge	"	"	"	"	"
J. L. Walker Studentship	"	"	"	"	£400–£500 p.a.	Open to graduates of any university	"
Trinity College Research Studentship †	Unrestricted	Trinity College	"	2–3 years	Not exceeding £300 p.a.	Open to graduates who have not commenced residence in the university of Cambridge and are preparing for the Ph.D. degree	The Senior Tutor, Trinity College, Cambridge
Rouse Ball Studentship †	Mathematics	A foreign university or school	Dom.	1 year	£136	Restricted to members of Trinity College holding B.A. degree and not yet eligible for M.A.	The Tutor, Trinity College, Cambridge

Strathcona Research Studentship †	Unrestricted	St John's College	U.K.	1 year (may be renewed)	£200	Open to graduates of any university	The Senior Tutor, St John's College, Cambridge
Philip Baylis Studentship †	Mathematics	"	"	1 year		Open to graduates of any university, but preference to members of the college	"
Emmanuel College Research Studentship †	Unrestricted	Emmanuel College		2 years (may be renewed)	£150 p.a.	Open to graduates of universities other than Cambridge. Preference to those who have already done research for 1 year	The Master of Emmanuel College, Cambridge
Emmanuel College Research Studentship †	Research leading to Ph.D. degree	Abroad by permission	Dom.	"	"	Restricted to graduates of Emmanuel College	—
Gabriel Stokes Studentship	Physics or cognate subjects	Pembroke College	"	3 years renewable up to maximum of 5 years	About £425 p.a.	Open to graduates between 23 and 30 preferably of Cambridge	The Master, Pembroke College, Cambridge
CAMBRIDGE WOMEN'S COLLEGES:							
Mary Ewart Travelling Scholarship *	—	Unrestricted	"	1 year	£200	Restricted to graduates of Newnham College, who need not necessarily be engaged in research	The Principal, Newnham College, Cambridge
Newnham College Fellowship for Research *	—	Abroad by permission	"	3 years	£250 p.a.	Restricted to graduates of Newnham College. Award is made on a dissertation or other written work	"
Tucker and Price Scientific Research Fellowship	Mathematical, physical and natural sciences	Girton College	U.K.		"	Open to graduates of any university	The Secretary, Girton College, Cambridge
Ethel Sargant Studentship	Botany	Girton College	"	Not stated	£100 per year	"	"
Hertha Ayrton Bye-Fellowship	Physical sciences	Girton College	"	"	£150 a year	"	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to :
CARNEGIE TRUST FOR THE UNIVERSITIES OF SCOTLAND :							
Carnegie Fellowships	Science, medicine, history, economics, modern languages and literature	Unrestricted	U.K.	2 years (may be extended to 3)	£250 p.a. and allowance for special expenses	Restricted to graduates of Scottish universities who have shown their capability to advance knowledge by original research. Candidates must be nominated by a professor or other head of a university department. New regulations coming into force on 1 October 1947	J. R. Peddie, Esq., C.B.E., D.Litt., Secretary, Carnegie Trust for the Universities of Scotland, The Merchants Hall, 22 Hanover Street, Edinburgh
Carnegie Scholarships	,,	,,	,,	,,	£150 for first two years. £175 for third year	Restricted to graduates of Scottish universities preferably with honours in at least one of the groups stated, who desire to devote themselves to research. Candidates must be nominated by a professor or other head of a university department. New regulations coming into force on 1 October 1947	,,
CHADWICK TRUSTEES :							
Travelling Scholarships (awarded from time to time)	Hygiene	Abroad	,,	1 year (may be renewed)	£150–£400 p.a.	Open to British subjects between 25 and 30 years of age holding a degree in a British university	The Clerk to the Chadwick Trustees, Chadwick Trust, 204 Abbey House, Westminster, London, S.W.1
COLONIAL OFFICE :							
Colonial Agricultural Scholarships (up to 25) †	(*a*) Specialization in some branch of agricultural science. (*b*) General Agriculture	1st year in Great Britain; 2nd year usually at the Imperial College of Tropical Agriculture, Trinidad	D.-D.	Normally 2 years but may be 1 year for advanced student or exceptionally 3 years	£260 p.a. plus fees up to £75 and travelling expenses for the year spent abroad plus £10 for the purchase of approved books	Restricted to candidates with an honours degree preferably in science (including botany) or a degree or diploma (entailing at least 3 years' study) in agriculture or horticulture. Scholarships are awarded with a view to subsequent appointment in the Colonial Service	The Director of Recruitment (Colonial Service), 2 Richmond Terrace, London, S.W.1, by 15 June

Colonial Veterinary							
(i) *Scholarships* (awarded only in exceptional cases) †	Veterinary science	Great Britain	U.K.	(i) 1 to 4 years according to needs	(i) £260 p.a. plus not more than £10 for the purchase of approved books	Candidates should possess (i) a science degree or equivalent qualification; (ii) the diploma of membership of the Royal College of Veterinary Surgeons	The Director of Recruitment (Colonial Service), 2 Richmond Terrace, London S.W.1 by 15 June
(ii) *Studentships* (up to 10) †	”	”	”	(ii) Normally 1 year	(ii) £300 p.a. plus £10 for approved books		
DURHAM, UNIVERSITY OF:							
Philip Buckle Memorial Scholarship	Agriculture including agricultural zoology	Unrestricted	Dom.	3 months or more (annual award). Interest on £1500		Restricted to graduates (B.Sc.) of not more than 1 year's standing of the department of agriculture of King's College. Should there be no graduate of the department of agriculture, a graduate of the department of zoology will be eligible	The Registrar, King's College, University of Durham, Newcastle-on-Tyne, by 15 May
College Post-Graduate Studentship (6)	Unrestricted	”	”	1 year (may be renewed)	£100 each; may be increased up to £150	Restricted to graduates of Durham University who have studied in King's College during the final 2 years of work for the degree of Bachelor	”
Earl Grey Memorial Fellowship	Science or commerce	”	”	”	£300	Restricted to graduates in science or commerce of Durham University	”
William Black Noble Memorial Studentship	Commerce, arts or science	”	”	”	£100; may be increased up to £150	Restricted to graduates in the faculties of commerce, arts or science. Preference to graduates in the faculty of commerce	”
Pemberton Studentship	Unrestricted	”	”	”	”	Restricted to graduates in pure science who have studied in King's College during the final 2 years of work for the degree of B.Sc.	”
EDINBURGH, UNIVERSITY OF:							
Dickson Travelling Fund		”		Duration variable	About £90 p.a. available for grants	Grants for travel may be made to graduates in any faculty of not more than 3 years' standing	The Secretary, University of Edinburgh, by 15 May

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
EDINBURGH, UNIV. OF—*contd.*:							
Drummond Mathematical Scholarship	Mathematics and natural philosophy	May be specified by senators	Dom.	2 years	£140 p.a.	Restricted to graduates in arts of not more than 3 years' standing who have taken honours in mathematics and natural philosophy	The Secretary, University of Edinburgh
Shaw Macfie Lang Fellowship	Determined by the Senate and the University Court	British or foreign university	"	"	£200	Open to graduates with honours of any Scottish University of not more than 4 years' standing	"
Maclaren Scholarship	Mathematics and natural philosophy	May be specified by senators	"	"	£200 p.a.	Open to a master of arts with honours in mathematics and natural philosophy of not more than 3 years' standing. Age limit 30	"
Scott Travelling Scholarship	Selected groups of subjects in rotation	Unrestricted	"	1 year	£77	Restricted to graduates in arts of the university of not more than 3 years' standing. Preference to natives of Perthshire	"
M'Cosh Bursary	Medicine	Medical schools of Europe and America	—	"	£312	Restricted to graduates of Edinburgh University in medicine and surgery of not more than 3 years' standing	The Dean of the Medical Faculty, University of Edinburgh, by 3 July
Paterson Travelling Scholarships in Surgery	Surgery	Unrestricted	Dom.	Variable	£100 p.a.	Restricted to graduates of Edinburgh University who desire to travel for the purpose of studying surgery	"
GLASGOW, UNIVERSITY OF:							
Bryce Mathematical Fellowship †	Mathematics	At least 1 year at a university other than Glasgow	"	4 years	£300	Restricted to Glasgow graduates who have taken honours in mathematics	The Registrar, University of Glasgow
J. R. K. Law Scholarship †	Applied science	Overseas university or scientific institution in U.S.A., Canada or France	"	2 years (may be extended)	£190 p.a.	Restricted to Glasgow Bachelors of Science who are British subjects	"

GOLDSMITHS' COMPANY							
Senior Studentships	Humanities, science, agriculture, technology, economics, music or art	In the Dominions	"	2 years	Up to £400 p. a.	Graduates of a university in the U.K., of either sex, of British parentage and who are in need of assistance to enable them to pursue overseas study, must be recommended by the authorities of their university. Normal age limit 24, but allowance may be made for war service	The Clerk, Goldsmiths' Hall, London, E.C.2, by 1 June
GROCERS' COMPANY:							
Scholarship	Medical research	Approved hospitals or laboratories	U.K., Dom.	"	£300 for first year and £450 for second. Up to £150 p.a. grant for equipment, etc.	Open to British subjects. Age limit 35. Application by 1 June	The Clerk to the Company, Grocers' Hall, Princes Street, London, E.C.2, by 1 May
IMPERIAL CHEMICAL INDUSTRIES LTD:							
Research Fellowships	88 in physics, chemistry and sciences derived therefrom including chemotherapy	Universities of Birmingham, Cambridge, Durham, Edinburgh, Glasgow, London, Leeds, Liverpool, Manchester and Oxford	U.K.	3 to 5 years	£600 p.a.	12 fellowships are tenable at each of the universities of Oxford, Cambridge and London; 8 each at Birmingham, Edinburgh, Glasgow, Leeds, Liverpool and Manchester; 4 at Durham	The Registrar of any of the universities referred to in the adjoining column
INSTITUTION OF ELECTRICAL ENGINEERS:							
Ferranti Scholarship	Electrical engineering	(At approved establishment which may, at discretion of Council, be outside the British Isles, either in a Dominion or elsewhere	D.-D.	2 years	£250 p.a.	If any of these scholarships are held abroad an extra grant may be made to cover travelling expenses. Open to British subjects, students or graduates of the Institution, who have completed degree or diploma course approved by Council	The Secretary, The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2
Oliver Lodge Scholarship	"		"	1 year, possibly 2	£250		
Swan Memorial Scholarship	"		"	1 year	£120		
C. P. Sparkes War Thanksgiving Fund	"		"	"	A grant up to £100		

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
LEEDS, UNIVERSITY OF:							
Ellison Senior Fellowship	Pure chemistry, applied chemistry or physics	University of Leeds	U.K.	1 year renewable up to 3 years	£300 p.a.	Open to qualified chemists	The Registrar, University of Leeds
Proctor Memorial Fellowship	Research relating to leather	"	"	1 year renewable for second	£140 p.a.	—	"
Gas Research Fellowship	Chemistry of gases and combustion	"	"	1 year (may be renewed)	£350	Open to any qualified candidate, but preference given to one entering Coal gas industry	"
Clothworkers' Company Fellowships	Research in subjects related to textile industry or colour chemistry and dyeing	"	"	"	£160	Open to graduates of any university	"
LEVERHULME RESEARCH FELLOWSHIPS (indefinite number)	Research in science	At approved institution	U.K., Dom., D.-D.	Up to 2 years	Adjusted to individual needs	Open to all British-born subjects normally resident in U.K. but condition of residence can be waived at discretion of Advisory Committee	The Secretary, Leverhulme Research Fellowships, 7 Bedford Road, London, W.C.1
LISTER INSTITUTE OF PREVENTIVE MEDICINE							
Research Studentships (2)	Preventive medicine	Lister Institute, London	U.K.	1–2 years	£250 p.a.	Open to subjects of the British Empire. Vacancies advertised as they occur	The Secretary, Lister Institute of Preventive Medicine, Chelsea Bridge Road, London, S.W.1
Grocers' Company Research Studentship	Biochemistry	The Lister Institute	"	1 year (may be renewed)	£250	Open to British subjects	The Secretary, Lister Institute of Preventive Medicine, Chelsea Bridge Road, London, S.W.1
Jenner Memorial Research Studentship	Bacteriology	"	"	"	"	"	"
LIVERPOOL UNIVERSITY:							
John W. Garrett International Fellowship	"	United Kingdom	"	1 year (may be renewed)	£100	Awarded to members of universities or medical schools of United States or foreign countries	The Registrar, University of Liverpool
Johnston Colonial Fellowship	Biochemistry	"	"	"	"	Awarded to members of universities or medical schools of the Colonies	"

Oliver Lodge Fellowship	Physics	Liverpool University	"	1 year (renewable for a second and third year)	£120 p.a.	Open to any person qualified to undertake original research or advanced teaching, but preference to graduates of the university	"
Ethel Boyce Fellowship	Gynaecological pathology and bacteriology	Liverpool University or elsewhere by special permission	"	1 year (may be renewed)	£100 p.a.	Open to fully qualified medical students	"
Robert Gee Fellowship	Anatomy	Liverpool University	"	1 year	"	Open to qualified persons, but preference to graduates of the university	"
Thelwall Thomas Fellowship	Surgical pathology	"	"	1 year (may be renewed)	£150 p.a.	—	"
Munitions Committee Fellowship	2 in engineering	Liverpool University	"	1 year (may be renewed)	Each £250 p.a. for the first year and £350 p.a. for the second year	Open to qualified persons, but preference to graduates of the university	"
Ridgeway Research Scholarship	Tuberculosis or crippling diseases of children	Liverpool Open-air Hospital for Children and Liverpool University	"	1 year	£103 p.a.	Open to persons possessing qualifications in medicine	"
Evans, Son Lesher and Webb Research Studentship	Biochemistry	Liverpool University	"	2 years	£150 p.a.	Open to (*a*) any honours graduates in chemistry or (*.b*) any candidate for PhD. who has completed one year's research on biochemistry or a related field	"
Edward Forbes Exhibition	Marine biology	Liverpool Marine Biological Station	"	1 year	£6 p.a.	Open to post-graduate-students of the university or, in default of such, post-graduate students of any university	"
Charles Brotherton Scholarships	2 in any one of the departments of chemistry	Liverpool University	"	1 year (may be renewed)	£150 p.a.	Open to graduates of not more than one year's standing who have obtained degree of B.Sc. with first or second class honours in chemistry and who have declared their intention to enter upon a career in chemical industry	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
LONDON COUNTY COUNCIL:							
Robert Blair Fellowships	Applied science and technology	Abroad	Dom.	1 year (may be renewed for further year)	£450 each	Open to British subjects of at least 21 years of age. Preference to students of engineering, and to those who have completed a course of study in London institutions or have been identified with the London teaching service. At present awards in abeyance	The Education Officer, County Hall, London, S.E.1, by 1 June
Maudsley Hospital Research Fellowship in Psychiatry	Psychiatry	Maudsley Hospital and Pathological Laboratory of the London County Council	U.K.	1 year (renewable for further 2 years)	£300 p.a.	—	The Chief Officer, Mental Hospitals Department, County Hall, London, S.E.1
LONDON, UNIVERSITY OF:							
Keddey Fletcher-Warr Studentships	Science	Abroad by permission	U.K., Dom.	3 years (may be renewed)	£200 p.a. each	Restricted to graduates of a British university who are of European descent. Preference to graduates of the University of London	The Academic Registrar, University of London, Senate House, London, W.C.1
Gilchrist Studentship for Women *	Unrestricted	Unrestricted	Dom.	1 year	£100	Restricted to honours graduates of the University of London of not more than 3 years' standing	,,
Leon Bequest	Unrestricted, but preference to subjects in fields of economics or education	,,	U.K., Dom.	1 year (may be renewed)	£400	—	,,
Mary Scharlieb Research Studentship	Medical research	,,	Dom.	1 year and normally renewable for second if progress satisfactory	£250 p.a.	Restricted to graduates of the University of London who are either registered medical practitioners or qualified to undertake medical research	The Academic Registrar, University of London, Senate House, London, W.C.1, by 28 February

University Travelling Studentships (small number of)	Unrestricted	Abroad	„	1 year	To be fixed in relation to estimated expenses of successful candidates from fund of £2000 p.a.	Open to graduates of London University. Age limit 28, except in case of approved National Service	The Academic Registrar, University of London, Senate House, London W.C.1, by 1 May
Bedford College for Women, London: Notcutt Travelling Scholarship	„	„	„	„	£200	Restricted to graduates of Bedford College	The Registrar, Bedford College, London, N.W.1
Birkbeck College Research Studentships (2)	Unrestricted	Birkbeck College	„	1 year	£250	Holders to devote greater part of time to original research. Part of tenure can, by permission, be abroad	The Secretary, Birkbeck College, London, E.C.4
Guy's Hospital Dental Travelling Studentship †	Dentistry	Abroad	„	6 months	„	Open to graduates who have qualified at Guy's Hospital Medical School	The Dean, The Medical School, Guy's Hospital, London, S.E.1
Imperial College of Science and Technology (bursaries in concrete technology)	Not more than 11 in concrete technology	Imperial College, London	U.K.	1 year renewable for a second	£200 p.a.	—	The Rector, Imperial College, London, S.W.7
Beit Fellowship for Scientific Research	Science	Imperial College of Science and Technology	„	2 years	£300 p.a.	Open to candidates of European descent by both parents, without restriction as to nationality, holding a degree in any faculty in any university in the *British Empire*, or holders of a diploma or associateship of a college approved by the trustees	„
Henry George Plimmer Fellowship	Pathology	„	„	Duration not stated	£217	Open to graduates of universities of the British Empire	„
London School of Medicine for Women: Edith Pechey Phipson Post-Graduate Scholarship *	Medicine or surgery including obstetrics and gynaecology	London School of Medicine for Women	„	1 year (may be renewed)	£95	Open to all medical women, preferably coming from India or going to work in India	The Secretary, London School of Medicine for Women, 8 Hunter Street, London, W.C.1

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
LONDON, UNIV. OF—*contd.*:							
Luther Holden Research Studentship †	Surgery	Unrestricted	Dom.	Duration not stated	£150	Open to graduates of British nationality who have studied for at least 2 or 3 years at St Bartholomew's	Dean of the Medical College, St Bartholomew's Hospital, London, E.C.1
University College: Benington Memorial Hospital	Anthropology and craniology	University College	U.K.	1 year (awarded biennially)	About £55	The student elected must publish the result of his research as required by the nominators	The Registrar, University College, Gower Street, London, W.C.1
Leslie Pearce-Gould Scholarship	Medical or other scientific work	Unrestricted	Dom.	"	£245	Restricted to students of the medical school who have taken a medical degree at a university in Great Britain or Ireland, have held a resident appointment in the hospital and have not been qualified for more than 4 years	The Secretary, University College Hospital Medical School, London, W.C.1
MCCUNN TRUST:							
Medical Research Scholarships (4)	Medicine and allied subjects	Approved institution at home or abroad	"	1 year or more	£200 but may be increased after first year	Awarded to graduates of a Scottish university of not more than 5 years' standing	Messrs Mitchells, Johnston and Co., 160 West George Street, Glasgow
MANCHESTER MUNICIPAL COLLEGE OF TECHNOLOGY:							
Research Scholarships (not exceeding 15)	Technology (engineering, chemistry, textile industries, building physics and industrial administration)	College of Technology, Manchester	U.K	year	Not exceeding £70 each	Open to graduates of any university in the British Empire, and other persons possessing special qualifications. Candidate to be British subject	The Registrar, College of Technology, Manchester
MANCHESTER, UNIVERSITY OF:							
Sheridan Delépine Fellowship	Preventive medicine	Manchester	"	"	£300	Open to medical graduates of approved universities or persons holding approved registrable qualifications	The Registrar, University of Manchester
Grisedale Scholarship for Biological Research	Botany or zoology	"	"	1 year (may be renewed)	£200	Open to graduates of approved universities	"
John Harling Fellowship	Physics	"	"	"	"	Open to persons furnishing satisfactory evidence of ability to pursue original research	"

Knight Fellowship	Mental diseases	"	"	1 year (awarded triennially)	£150	Open to graduates of approved universities	"
Leech Fellowship	Medicine	Unrestricted	Dom.	1 year	£100 (possible grant of £20)	Open to graduates of the University of Manchester	"
Pilkington Fellowship	Cancer Research	Manchester	U.K.	"	£300	Open to persons possessing qualifications in medicine or surgery approved by the University	"
Dr Robert Angus Smith Scholarship	Sanitary science	"	"	1 year (may be renewed)	£150	—	"
Dickinson Travelling Scholarship in Medicine	(*a*) Medicine and (*b*) pathology, physiology or bacteriology or other subject approved by the Trustees	Abroad	Dom.	1 year	£300	Restricted to candidates who have graduated with distinction in medicine and surgery at the University of Manchester	"
Osborne Reynolds Research Fellowship	Engineering or related sciences	Manchester	U.K.	1 year but may be extended	£200	Open to graduates of any university	The Registrar, University of Manchester, before 1 May
Joseph Roberts Greatorex Scholarship in Engineering	Engineering	At Manchester or, for graduates of the university, at any approved institution	U.K., Dom.	1 year (may be renewed)	"	Open to graduates of Honours School of Engineering at the University who have subsequently completed at least 1 year's research in the engineering department. Also open to other suitably qualified candidates	The Registrar, University of Manchester, before 20 June
Bishop Harvey Goodwin Mathematical Scholarship	Mathematics	Manchester	U.K.	1 year	£60 to £70	Open to graduates in Honours School of Mathematics at the University or other suitably qualified candidates	"
Philip Buckle Research Scholarship in Agricultural Zoology	Agricultural zoology or agricultural botany	"	"	1 year (may be renewed)	£120 plus laboratory fees	Open, in first instance, to graduates in science of the university or lacking such to any candidate having the required qualifications	"
Imperial Chemical Industries Ltd. (Dyestuffs Group) Scholarships	Organic chemistry	"	"	1 year	£300 p.a. is available for provision of scholarships	Candidates must have studied chemistry at the university or some other approved institution	The Registrar, University of Manchester, by 1 June

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
MEDICAL RESEARCH COUNCIL:							
Grants (see also Rockefeller Medical Fellowships and Dorothy Temple Cross Fellowships)	Medicine, surgery and the allied sciences	Normally Great Britain, but abroad in exceptional cases	Dom. (when applicable)	Variable, 1 year but renewable up to 3 years	Variable	Grants are made to qualified investigators in respect of approved programmes of research work to be carried out in universities, medical schools, hospitals, and other institutions	The Secretary, Medical Research Council, 38 Old Queen Street, London, S.W.1
Dorothy Temple Cross Research Fellowships (awarded by Medical Research Council)	Tuberculosis	Unrestricted but ordinarily outside Great Britain	Dom.	1 year (may be renewed)	£450 p.a. for single Fellows and £650 p.a. for married, and travelling expenses; senior awards of greater value may be made	Restricted to candidates intending to devote themselves to the advancement of teaching or research of curative or preventive treatment of tuberculosis in all or any of its forms, and possessing suitable medical, veterinary or scientific qualifications	"
The Rockefeller Foundation: Fellowships in Medical Science (awards in U.K. made by Medical Research Council)	Medicine, surgery and the allied sciences	Unrestricted but principally the United States	"	1 year	£450 for single Fellows and £650 for married, and travelling expenses	Open to graduates who have had training in research work and are likely to profit by further work at a centre abroad before taking up position for higher teaching or research in the British Isles	"
Post-Graduate Studentships in Clinical Science and Experimental Pathology (6)	Medical science related to disease in human beings	Any approved institution	U.K., Dom. (?), D.-D. (?)	"	£200	Open to British medical graduates who have held house appointments	The Secretary, Medical Research Council, 38 Old Queen Street, London, S.W.1
Research Fellowships (4)	"	"	"	1 year (may be renewed)	£250 first year, £300 second	"	"
NUFFIELD FOUNDATION:							
Visiting Lectureships	—	—	D.-D.	—	—	Grants to assist eminent persons in various fields to visit other parts of the Commonwealth. These grants will take into account cost of travel by air	The Secretary, The Nuffield Foundation, 12–13 Mecklenburgh Square, London, W.C.1

Colonial Service Scholarships (1945–48)	Medicine or sciences associated with biological studies	Anywhere in Commonwealth or Empire	—	2 to 4 years	£200–£350 p.a.	To enable promising officers of Dominion or Colonial origin in the subordinate grades of the Colonial Service to qualify for promotion to higher grades	"
Nuffield Medical Fellowships	Medicine	United Kingdom or abroad	D.-D.	1 to 3 years	£500–£800 p.a.	Plus travelling expenses abroad. Open to men and women with university degree in medicine registrable in the U.K., and normally resident in the U.K.	"
Nuffield Dental Fellowships	Dentistry	"	U.K.	"	£400–£800	Plus travelling expenses abroad. Open to candidates (i) with dental qualification registrable in the U.K., who require additional training in pure and applied science to fit them for an academic career in dentistry in the U.K.; (ii) with university degree in medicine or science, who require training that will qualify them to undertake teaching and fundamental research on dental health and disease	"
Nuffield Dominion Medical Travelling Fellowships	Medicine	United Kingdom	"	1 to 2 years	£300–£800 p.a.	Plus travelling expenses for Fellow and wife to and from U.K. Sums available for 1946–47 are £6000 each for Australia, Canada and India, £4000 each for New Zealand and South Africa. For medically qualified men and women from these countries, who ultimately intend to undertake research and teaching in their own countries, to enable them to obtain post-graduate training and experience in the U.K. Preference will be given to those who have served with the armed or auxiliary services of the Crown	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
UNIVERSITY COLLEGE, NOTTINGHAM:							
Research Scholarships (3)	Pure and applied science, to read for a further degree	University College, Nottingham	U.K.	1 or 2 years	Up to £100 each	Open to graduates of any university within the British Empire	The Registrar, University College, University Park, Nottingham
Carr Scholarship	Geology, botany or entomology	"	"	"	£200 per annum	Open to graduates of any approved British university	"
OXFORD, UNIVERSITY OF:							
Radcliffe Travelling Fellowships (2)	Medical science	Unrestricted	Dom.	2 years	£300 p.a. each	Restricted to persons who have passed the examinations for the degrees of B.A. and B.M. and have not exceeded 4 years from the time of passing for the B.M.	The Master, University College, Oxford
Jesus College, Senior Scholarship (King Charles I scholarship) †	Unrestricted	Jesus College, Oxford	U.K.	Maximum of 5 years	Maximum of £100 p.a.	Candidates must be either born in Channel Islands or educated at either Victoria College, Jersey, or Elizabeth College, Guernsey Candidates must be unmarried Candidates must be either qualified for degree of B.A. at Oxford, or must be a student reading for D.Phil., B.Sc. or B.Litt. at Oxford	The Principal, Jesus College, Oxford
George Herbert Hunt Travelling Scholarship	Medicine	Unrestricted	Dom.	Duration not stated	About £100 (awarded biennially)	Restricted to graduates in the faculty of medicine	The Dean of the Medical School, University Museum, Oxford
Philip Walker Studentship	Pathology	University of Oxford	U.K.	1 to 5 years	£200 p.a.	Open to graduates of any university	The Professor of Pathology, University Museum, Oxford
Lady Margaret Hall Research Scholarship *	Unrestricted	Lady Margaret Hall, Oxford	"	3 years (may be renewed)	£300 p.a.	"	The Principal, Lady Margaret Hall, Oxford
Lady Margaret Hall Senior Scholarship *	"	"	"	1 year (may be renewed)	£100 p.a.	"	"
Susette Taylor Annual Fellowship *	"	Abroad	D.-D.	1 year	£150	Open to graduates of any university but preference given to Oxford graduates	"

Susette Taylor ... ship *							
Mary Ewart Travelling Scholarship *	"	Unrestricted	Dom.	Duration not stated	£150–£200	Awarded from time to time to past students of Somerville College	The Principal, Somerville College, Oxford
Lady Carlisle Research Fellowship *	"	Somerville College, Oxford	U.K.	5 years (renewable up to 10)	£250 p.a. with free board and residence for 45 weeks of year	Open to unmarried women and widows (European race and naturalized Jewesses)	"
RAMSAY MEMORIAL FELLOWSHIPS (2)	Chemical research	At a university or institution in the United Kingdom, in exceptional circumstances in other parts of the British Empire and also elsewhere	Dom., D.-D.	2 years (may be renewed)	£300 p.a. and allowance of £50 for expenses	One fellowship is restricted to candidates nominated by the University and the Royal Technical College, Glasgow	The Secretary to the Trustees, Ramsay Memorial Fellowships University College, Gower Street, London, W.C.1
RHODES SCHOLARSHIPS : †							
Canada : 1 annually to each Province (to Quebec and Ontario 2 each)	For preparation in final honours school or for research degree (B.Litt., B.Sc., D.Phil.)	University of Oxford	U.K.	3 years	£400 p.a. each	Candidates must be between 19 and 25 years of age and unmarried. They must be citizens of the country from which they come and must have at least 2 years' standing at a regular degree-granting college or university except in a case where there is no such institution. Candidates may eliminate time spent in war service in reckoning age	The Secretary to the Rhodes Trustees, Seymour House, Waterloo Place, London, S.W.1
Australia : 1 annually to each State			"	"	"		
New Zealand : 2 annually			"	"	"		
South Africa : 1 each to Natal; Transvaal; Orange Free State; Cape Province; S.A. College School in Cape Town; Diocesan School of Rondebosch; Boys' High School, Stellenbosch; St Andrew's College School, Grahamstown; Eastern Province; Rhodesia (maximum of 3 annually)			"	"	"		
India : 2 annually			"	"	"		
Jamaica : 1 annually			"	"	"		
Newfoundland : 1 annually			"	"	"		
Bermuda : 1 annually			"	"	"		
Malta : 1 annually			"	"	"		
East Africa : 1 triennially			"	"	"		

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ROYAL COLLEGE OF PHYSICIANS:							
Leverhulme Research Scholarships (2) (awarded by the Royal College of Physicians)	Medicine (investigation of some clinical problem of disease in man	Preferably in the United Kingdom.	D.-D.	1 year but may be renewed from year to year	£500 p.a.	Candidates to be not less than 25 years of age	The Secretary, Royal College of Physicians, Pall Mall East, London, S.W.1
MacKenzie Mackinnon Research Fellowship (Royal College of Physicians and Royal College of Surgeons)	Scientific medical research	Unrestricted	Dom.	1 year (renewable up to 3 years)	Variable, at discretion of Committee of award	Candidates must hold a medical qualification registrable in Great Britain or Ireland, or a university degree, and must be nominated by a medical school	"
Saltwell Research Fund	Research in cure or prevention of all or any of following diseases: cancer, rheumatism, malaria and morbid conditions of the prostate gland	"	D.-D.	1 year but may be renewed for second and third	Income from fund	The Trustees shall have absolute discretion to appoint any suitable candidate irrespective of sex, nationality or medical qualification	
ROYAL COLLEGE OF PHYSICIANS AND ROYAL COLLEGE OF SURGEONS:							
Streatfeild Research Studentships	Medicine or surgery	Unrestricted	Dom.	3 years	£250 p.a.	—	The Secretary, Royal College of Physicians or Royal College of Surgeons
ROYAL COLLEGE OF SURGEONS							
Bland-Sutton Research Scholarship	Medicine	Bernhard Baron research laboratories of the Royal College of Surgeons	U.K.	Not more than 3 years	£300 p.a.	—	The Secretary, Royal College of Surgeons of England, Lincoln's Inn Fields, London, W.C.2
Leverhulme Research Scholarships (2)	Surgical or medical problems	—	"	1 year (renewable up to 3)	£400 p.a. and £100 for expenses	—	"
Prophit Research Studentships (2)	Cancer research	—	D.-D.	1 year (renewable up to 5)	£500 p.a, and gran t not exceeding £200 p.a. for travelling	Awarded by Special Trustees on nomination of The Royal College of Surgeons	"

ROYAL COLLEGE OF SURGEONS AND UNIVERSITY OF LIVERPOOL AND LIVERPOOL MEDICAL INSTITUTION							
Robert Jones Travelling Research Fellowship	Probably orthopaedics	At least 6 months abroad	"	1 year	£250	—	The Secretary, Royal College of Surgeons, or University of Liverpool or Liverpool Medical Institution
ROYAL COMMISSION FOR THE EXHIBITION OF 1851:							
Post-Graduate Scholarship †	Naval architecture	Any institution at home or abroad approved by the Commissioners	Dom.	2 years	£250	Open to British subjects under the age of 30 on the recommendation of King's College, Newcastle, R.N. College, Greenwich, the University of Glasgow or the University of Liverpool. Scope and conditions now under review	The Secretary to the Commissioners, Royal Commission for the Exhibition of 1851, 1 Lowther Gardens, Exhibition Rd., London, S.W.7
Overseas Science Research Scholarships (10 annually) †	Science	Any institution approved by the Commissioners. (Only in exceptional circumstances will a scholar be permitted to hold the scholarship in the Dominion in which he (or she) has received scientific education)	D.-D.	2 years (may be extended to 3)	£350 p.a. An additional grant not exceeding £50 p.a. may be made towards university fees	Open to British Dominion students of universities invited by the Commissioners to nominate candidates. Age limit 26. Nominations from South Africa, Eire and India receivable by 1 May; from Australia, New Zealand and Canada by 1 June	"
Senior Studentships (14 annually) †	"	Any institution at home or abroad approved by the Commissioners	Dom.	2 years (exceptional cases 3)	£500 p.a. An additional grant not exceeding £50 p.a. may be made towards university fees, etc.	Open to British subjects of not more than 30 years of age on the recommendation of professors and heads of departments through the executive authorities of U.K. institutions invited to nominate. Holder is not permitted to hold any other occupation likely to interfere with his or her time. He is not debarred from holding a position of emolument, but in such cases the studentship may be modified	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ROYAL INSTITUTION:							
Dewar Research Fellowship	Some branch of science	Royal Institution	U.K.	3 years (may be renewed for further 2 years)	£400	Open to any suitably qualified candidate	The General Secretary Royal Institution, 21 Albemarle Street, London, W.1.
THE ROYAL SOCIETY:							
Mackinnon Research Studentship	Pathology and other natural and physical sciences	Unrestricted	D.-D.	2 years (renewable up to 5 years)	£300 to £500 p.a.	Awarded from fund bequeathed for the purpose 'of furthering natural and physical science, including geology and astronomy, and of furthering original research and investigation in pathology.' Regulations now under review	The Assistant Secretary, The Royal Society, Burlington House, London, W.1
Moseley Research Studentship	Experimental science	,,	,,	2 years (renewable up to 5 years)	£300 to £500 p.a.	Awarded from bequest for 'the furtherance of experimental research in pathology, physics and chemistry, or other branches of science, but not in pure mathematics, astronomy or any branch of science which aims merely at describing, cataloguing or systematizing.' Regulations now under review	,,
Foulerton Research Fund—							
(a) Research Professorships	Medical research	In a place approved by the Royal Society	,,	5 years, renewable for successive 5-year periods	£1400 to £1500 p.a.	Whole time to be devoted to research on causes and cure of diseases	,,
(b) Research Fellowship	,,	,,	Dom.	3 years, renewable annually up to a maximum of 6 years	£700 p.a.	Restricted to British subjects to conduct researches in medicine or contributory sciences	,,
Yarrow Research Professorships	Research in mathematics, physical chemistry or engineering sciences	,,	,,	5 years, renewable for successive 5-year periods	£1000 to £1400 p.a.	—	,,
Smithson Research Fellowship	Research in natural science	In the University of Cambridge provided that an appropriate laboratory of that university is prepared to offer the necessary accommodation	U.K.	4 years in the first instance (renewable annually to a maximum of 8 years)	£800 to £900 p.a.	Awarded from a fund for the carrying on of original scientific research with a view to the discovery of new laws or principles rather than the exploitation of what is known	,,

necessary accommodation

Sorby Research Fellowship	Original scientific research	In one of the laboratories of the University of Sheffield. (This condition may, however, be dispensed with when the nature of the investigation requires that the work shall be done elsewhere)	,,	5 years but may in special circumstances be prolonged	£800 p.a.	Awarded from a fund whose income may be devoted to the establishment of a fellowship for the carrying on of original scientific research, the object being to promote the discovery of new facts rather than the teaching of what is known	,,
Warren Research Fellowships	Research in metallurgy, engineering, physics or chemistry	Unrestricted	D.-D.	4 years, renewable for further period of 4 years	Not less than £500 p.a.	Fellow's whole time to be devoted to research. Limited amount of teaching work might be allowed	,,
E. Alan Johnston and Lawrence Fellowship in Medicine	Causes of disease	—	U.K	2 years (may be renewed up to maximum of 5 years)	£700 p.a. with superannuation benefits	Open to British subjects	,,
ROYAL SOCIETY OF MEDICINE:							
William Gibson Research Scholarship *	Medicine	,,	D.-D.	2 years (may be renewed for a third)	£290 p.a.	Awarded from time to time to qualified medical women who are subjects of the British Empire	The Secretary, The Royal Society of Medicine, 1 Wimpole St, London, W.1
ST ANDREWS, UNIVERSITY OF:							
Armistead Bursary	Arts, science and medicine	Abroad by special permission and in exceptional circumstances	Dom.	1 year	£100	Restricted to graduates of University College, Dundee (University of St Andrews) in arts, science or medicine	The Secretary, University College, Dundee, by 15 September
William Strong Bursaries (2)	,,	,,	,,	,,	,,	,,	The Secretary, University College, Dundee
Clyde-Henderson Scholarship	,,	,,	,,	,,	,,	Restricted to graduates of University College, Dundee (University of St. Andrews) in arts, science and medicine and to a man and woman in alternate years	,,
Ramsay Scholarship	—	Tenable with permission at another university or institution	,,	2 years	£150	—	The Secretary, University of St Andrews

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ST ANDREWS, UNIV. OF—*contd.*:							
Bruce Scholarship	—	Tenable with permission at another university or institution	Dom.	2 years	£150	—	The Secretary, University of St Andrews
Berry Scholarship	—	"	"	"	£160	—	"
Guthrie Scholarships †	Classics and mathematics	A foreign university by special permission	"	4 years or less	£135 p.a. or more for shorter periods	Restricted to graduates of St Andrews (M.A. or B.Sc.). Age limit 23. Available 2 years out of 3 to candidates who attain distinction in classics and 1 year out of 3 to those who attain distinction in mathematics	The Secretary, University of St Andrews, by 1 Mar.
SALTERS' INSTITUTE OF INDUSTRIAL CHEMISTRY FELLOWSHIPS	Industrial chemistry	Unrestricted	"	Duration not stated	£250–£300	Restricted to chemists of graduate standing to enable them to undergo a special further training for careers in industrial chemistry. Suspended for the year 1946–1947	The Director of the Institute, Salters' Hall, St Swithin's Lane, London, E.C.4
SHEFFIELD, UNIVERSITY OF:							
Robert Styring Post-Graduate Scholarships	Metallurgy, physics or fuel technology	University of Sheffield	U.K.	1 year renewable up to maximum of 4 years	£100 p.a.	A candidate must ordinarily be of either English, Scotch or Welsh nationality and the child of parents, or a parent, who have, or has, resided in the City of Sheffield for not less than 4 years at the date fixed for the commencement of the scholarship. The period of residence may be relaxed in special cases. The Senate, may, at its discretion, award scholarships to competitors from Canada, Australasia or South Africa. The scholarships are open, subject to the foregoing clause, to graduates of the University of Sheffield or to other persons who have pursued approved courses of study in the university	The Registrar, The University, Sheffield

Ironmongers' Company Research Scholarships (2)	Cold working of steel and other ferrous metals	"	Dom.	1 year (may be renewed)	£150	Open to graduates who are British subjects of English, Scottish, Welsh or Irish birth. If a scholarship is renewed for a second year the scholar may be allowed to continue his research abroad. The scholarships are at present suspended	"
Ironmongers' Company Research Fellowship	Cold-working of steel and other ferrous alloys	" "	U.K.	Unspecified	£500 p.a.	Open to candidates with experience in metallurgical research	"
Tom Jackson Travel Fund	Glass technology	"	Dom.	—	—	This fund is to be applied to enable a student who has been trained in glass technology to benefit from a tour of inspection abroad. Further details will be published when the accumulated fund renders it possible to offer an award	"
SOUTHAMPTON, UNIVERSITY COLLEGE:							
Research Scholarships	Unrestricted	University College, Southampton	U.K.	2 years (under special circumstances for 3 years)	£150 p.a.	Preference to graduates of universities within the British Empire	The Registrar, University College, Southampton
Lady Tata Research Scholarships (4)	Blood diseases with special reference to leucaemias	Unrestricted	D.-D.	1 year normally; renewable up to a maximum of 3 years	£400 p.a.	Ordinarily awarded on a full-time basis, but a candidate may, by permission of the Trustees, be allowed to retain a part-time teaching post	Dr H. S. Patel, Lady Tata Memorial Trust, Capel House, New Broad Street, London, E.C.2
UNITED DAIRIES:							
Research Scholarship	A subject closely connected with dairying or dairy farming	"	Dom.	Duration, according to the nature of research undertaken	Value variable	Restricted to sons and daughters of farmers and smallholders resident in Cornwall, Devon, Dorset or Somerset. Candidates must have pursued for 1, 2 or 3 years a course in dairying and dairy farming. Normally they must be graduates of a university	The Honorary Secretary, United Dairies Scholarship Fund, 34 Palace Court, London, W.2

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
VETERINARY EDUCATIONAL TRUST:							
Wellcome Research Fellowship	Veterinary research	Any approved institution in the U.K.	U.K.	1 year (may be renewed for further 2 years)	£450	Open to candidates under 36 years having Membership Diploma of Royal College of Veterinary Surgeons or degree in any faculty in any university of British Empire, or equivalent for women	Dr W. R. Wooldridge Hon. Secretary, Wellcome Research Fellowships for Veterinary Research, London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1
WALES, UNIVERSITY OF:							
Ewen Maclean Research Scholarship	Obstetrics and gynaecology	Welsh National School of Medicine	"	1 year	£150	Open to graduates of any approved university or qualified medical practitioner	The Registrar, University of Wales, Cathays Park, Cardiff
Cecil Prosser Research Scholarship	Tuberculosis	"	"	"	£250	"	"
University Fellowships	Unrestricted	Any approved seat of learning or research	Dom.	2 years	£300	Restricted to graduates of the University	"
University Post-Graduate Studentships	"	Abroad by permission	"	"	£100 p.a.	Restricted to graduates of the University, on nomination by their college	"
Eyton Williams and Dr Samuel Williams Studentships	"	"	"	"	"	"	
Kemsley Travelling Scholarship	"	Abroad	"	1 year	£400	Restricted to graduates of the university of not more than 2 years' standing	"
WALES, UNIVERSITY COLLEGE OF:							
Scholarships for Research (4)	"	University College, Aberystwith	U.K.	"	Maximum of £150	Awarded from time to time	The Registrar, University College of Wales, Aberystwyth
Travelling Scholarships	"	Abroad	Dom.	Easter or summer vacation	£10 and upwards	Open to graduates of the University College of Wales, Aberystwyth, to encourage travel outside U.K. as a means of general education rather than for specific research	The Registrar, University College of Wales, Aberystwyth, by 1 February

SIR WILLIAM WHITE:							
Post-Graduate Research Scholarship	Naval architecture including shipbuilding and marine engineering	Unrestricted	Dom.	2 years	150 p.a.	Restricted to students of naval architecture who have taken a course of study with marked distinction at an approved university or college and who have at some time been employed in professional shipbuilding or engineering work. Age limit 30	Royal Naval College, Greenwich; Imperial College, London, S.W.7; the University of Liverpool; or King's College, Newcastle-on-Tyne

CANADA

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
BRITISH COLUMBIA, UNIVERSITY OF:							
Captain Leroy Memorial Bursary	Unrestricted	Any approved university	D.-D.	1 year	$250	Restricted to graduates of the University of British Columbia	The Registrar, University of British Columbia, Vancouver
CANADIAN FEDERATION OF UNIVERSITY WOMEN:							
Travelling Fellowship *	"	Place chosen by the selection committee and the candidate	"	"	$1250	Restricted to women, under 35 years of age, graduates of a Canadian university, preferably with 2 years of graduate work, and research in view	Dr Geneva Misener, University of Alberta, Edmonton
DALHOUSIE UNIVERSITY, HALIFAX, NOVA SCOTIA:							
Travelling Fellowship for Women *	—	Abroad	"	—	$1500	—	
IMPERIAL ORDER DAUGHTERS OF THE EMPIRE:							
Postgraduate Overseas Scholarships	British and Imperial history, economics and government of Empire and Dominion, or *any subject vital to interest of Empire*	Great Britain	U.K.	1 year	$1400 each	Open to men and women candidates	I.O.D.E., Toronto, Ontario

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
MANITOBA, UNIVERSITY OF:							
Travelling Fellowships (2)	One in arts, one in science	Unrestricted	D.-D.	1 year	$400	Restricted to candidates who have been in residence for at least 3 years in the University or an affiliated college. Age limit 25. Fellowship in science awarded biennially	The Registrar, University of Manitoba, Winnipeg
MCGILL, UNIVERSITY OF:							
Macdonald College Agricultural Alumnae Association Graduate Scholarship	Agriculture	Any approved university or other institution	"	"	About $200	Restricted to graduates in agriculture of Macdonald College	The Secretary, Macdonald College, Ste. Anne, P.Q.
McGill Delta Upsilon Memorial Scholarship	Unrestricted	Unrestricted	"	"	$950	Restricted to graduates of McGill University	The Registrar, McGill University, Montreal
Moyse Travelling Fellowships (2)	One in arts, one in science	Europe	U.K.	"	$1500 each	Restricted to graduates of McGill University distinguished in literary subjects, or in pure and applied science	"
NATIONAL RESEARCH COUNCIL (WASHINGTON):							
Fellowships	Biological sciences	Unrestricted	D.-D.	Duration not stated	Minimum $1800	Open to graduates holding a doctor's degree or its equivalent, and of Canadian citizenship	Secretary of Board of Fellowships in Biological Sciences, National Research Council, Washington, D.C.
Medical Fellowship	Medicine	"	"	"	Unmarried fellow, $1800; married fellow, $2300	Open to graduates holding M.D. or Ph.D. degree or its equivalent, of Canadian citizenship	Chairman of Medical Fellowship Board, National Research Council, Washington, D.C.
ONTARIO COLLEGE OF EDUCATION:							
Exchange Student Teacher Fellowship	Educational training	Training centre attached to any Scottish university	U.K.	1 year	$1500	Open to teachers in secondary schools in Ontario	—
William E. Wilder Fellowship †	Unrestricted	Great Britain	D.-D.	1 year (may be renewed)	"	Restricted to graduates of the University of Toronto	—

William E. Wilder Fellowship†	Unrestricted						
Queen's University, Kingston, Ontario:							
George Christian Hoffman Fellowship	Pathology	Europe or U.S.A.	U.K.	1 year (may be renewed)	$1000 (?)	—	The Secretary, Faculty of Medicine, Queen's University, Kingston, by 1 March
George Christian Hoffman Fellowships (2)	Surgery	"	"	"	$700 (?) each	—	,
Royal Society of Canada:							
Fellowship	Advanced research in literature, history, anthropology, sociology, political economy or allied subjects, in French or English; and in mathematics, chemistry, physics, geology, biology or subjects associated with any of these sciences	Institutions of learning and research, except in special circumstances, outside Canada	D.-D.	—	$1500	—	—
Saskatchewan, University of:							
Imperial Order Daughters of the Empire Saskatchewan Scholarship	—	—	—	—	$500	—	The Registrar, University of Saskatchewan
Consolidated Smelting Company Scholarship	—	—	—	—	$700 plus $400 for supplies	—	,
Saskatchewan Agricultural Research Foundation	—	—	—	2 years	$800 p.a.	Open to graduate students	"
Toronto, University of:							
George Brown Memorial Scholarship in Medical Science	Medicine (laboratory or clinical)	Approved medical school or hospital	D.-D.	1 year (awarded triennially)	Income from capital of £2000	Restricted to doctors of medicine of not more than 3 years' standing	The Registrar, University of Toronto
Nipissing Mining Company Research Fellowship	Mining engineering	Department of Mining Engineering, University of Toronto	"	Not stated	$1100 p.a.	Awarded to graduates of any university	Dean of School of Graduate Studies, University of Toronto

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
TORONTO, UNIV. OF—*contd.*:							
Margaret E. T. Addison Scholarship •	Postgraduate studies	University outside Canada	D.-D.	—	$750	Open to a woman graduate of Victoria College	—
J. S. McLean Fellowship	"	Abroad	"	—	$1250	Open to a graduate of University College	—

AUSTRALIA

University or Institute, etc.	Subject.	Where tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ADELAIDE, UNIVERSITY OF:							
Angas Engineering Scholarship	Engineering or allied subject	United Kingdom	U.K.	2 years	£200 p.a.	—	The Registrar, University of Adelaide (before 1 June)
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH:							
Overseas Studentship (varying number)	Pure and applied sciences	For study at an approved university or research institution abroad—normally in the U.K. or the U.S.A.	D.-D.	"	£A600 in U.K., £A800 in U.S.A. This includes £A100 towards fares and £A50 towards fees. The remainder is subject to Australian income tax	Students are required to give an undertaking that at the completion of their period of training abroad they will return to Australia and if required accept appointment to the staff of the Council for Scientific and Industrial Research at a certain minimum salary for a period of three years	Secretary C.S.I.R., 314 Albert Street, East Melbourne, C.2.
LINNEAN SOCIETY OF NEW SOUTH WALES:							
Macleay Fellowships (4)	For study and research	At Sydney or abroad	"	"	£400 p.a.	—	—
Macleay Fellowships (4)	"	"	"	"	£300 p.a.	—	—
Macleay Scholarships (2)	"	"	"	"	£250	—	—

Macleay Fellowships (4)	„	„	„	„	£250		
Macleay Scholarships (2)	„	„					
MELBOURNE, UNIVERSITY OF:							
Aitchison Travelling Scholarships	Unrestricted	Not tenable in Victoria	„	1 year (may be renewed)	£350	Restricted to graduates of not more than 2 years' standing	The Registrar, University of Melbourne
M.A. Bartlett Scholarships	„	Unrestricted	„	1 year	£100	Normally combined to form single award	„
Fred Knight Scholarships	„	„	„	„	£250		
R. J. Fletcher Research Scholarship	Medicine (cancer or anaesthetics)		„	1 year (may be renewed)	Income from £7500	—	Medical Research Funds Committee, c/o The Registrar, University of Melbourne
J. M. Higgins Research Foundation	Agriculture and Veterinary science	„	„	Unrestricted	Income from two Foundations of £2250 each	Other things being equal, research in use of fertilizers preferred	The Registrar, University of Melbourne
H. & D. Taft Interchange Scholarship	Unrestricted	Jerusalem	—	1 year	£200	Available to Melbourne graduates in alternate years	„
University of Melbourne Travelling Research Scholarships	„	Unrestricted	D.-D.	2 years	£300 p.a.	—	„
QUEENSLAND, UNIVERSITY OF:							
Walter and Eliza Hall Engineering Fellowship	Engineering	2 years overseas and 1 year at the University of Queensland	„	3 years	£500 p.a.	Awarded every 3 years	The Registrar, University of Queensland
Foundation Travelling Scholarships (2)	Unrestricted	Overseas	„	2 years	£250 p.a.	Awarded annually	„
Walter and Eliza Hall Travelling Scholarship	„	„	„	„	„	„	„
SCIENCE AND INDUSTRY RESEARCH FUND:							
Overseas Studentships	Pure and applied sciences	For study at an approved university or research institution abroad—normally in the U.K. or the U.S.A.	D.-D.	„	£A600 in U.K., £A800 in U.S.A. This includes £A100 towards fares and £A50 towards fees. The remainder is subject to Australian income tax	Students are required to give an undertaking that at the completion of their period of training abroad they will return to Australia and if required accept appointment to the staff of the Council for Scientific and Industrial Research at a certain minimum salary for a period of three years	Secretary to the Trustees, Science and Industry Research Fund, 314 Albert Street, East Melbourne, C.2.

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
SYDNEY, UNIVERSITY OF : ‡							
Jas. King of Irrawant Travelling Scholarship	Unrestricted	Approved overseas institution	D.-D.	2 years (max.)	£250 p.a.	Awarded every 2 years	The Registrar, University of Sydney
J. B. Watt Travelling Scholarship	"	"	"	2 years	£500 p.a.	—	"
Charles Kolling Travelling Scholarship in Mechanical Engineering	Engineering	"	"	2 years may be extended to 3 years in exceptional circumstances	£400 p.a.	Awarded alternate years	"
Barker Graduate Scholarship	Mathematics (arts, science, engineering)	University of Sydney	"	2 years	£250 p.a.	Awarded annually (if any candidate of sufficient merit)	"
Walter and Eliza Hall Fellowships	Medicine	Approved overseas institution	"	3 years	£300–£500 p.a.	Awarded every 3 years	"
	Engineering	2 years overseas and 1 year at University of Sydney	"	"	£300 p.a.	"	"
Edgeworth David Travelling Scholarship	Geology	Overseas	"	1 year	£250 p.a.	"	"
WESTERN AUSTRALIA, UNIVERSITY OF :							
Robert and Maude Gledden Travelling Scholarships	Surveying, engineering, mining or cognate subjects	Approved overseas institutions	"	1 or 2 years	£750	Awarded annually	The Vice-Chancellor, University of Western Australia, Perth
Hackett Research Studentships	Unrestricted	University of W. Australia, other Australian universities or overseas	"	"	£150 (plus £50 if overseas) and cost of books, etc.	"	"
Robert and Maude Gledden Travelling Scholarships	Applied science	Technical institutions in U.S. and overseas	"	Unspecified	Unspecified	—	"

‡ NOTE.—The following regulations have been made by the Senate in regard to the award of Travelling Scholarships :

1. That a normal age limit be imposed as a condition for holding a Travelling Scholarship, but that in special circumstances this limit may, with the consent of the Senate, be extended.
2. That the normal age limit be twenty-six years.
3. That all candidates be required to lodge a medical certificate along with their application.
4. That, except with the consent of the Senate, a Travelling Scholarship shall not be tenable by a married person.

NEW ZEALAND

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
CANTERBURY UNIVERSITY COLLEGE:							
Sir William Hartley Scholarship *	Unrestricted	Oxford, Cambridge or London or by special recommendation at any other European university	U.K.	3 years	£300 p.a. (and passage)	Restricted to graduates of the University of New Zealand who have studied at Canterbury College for at least 1 year, and will work for a doctorate at an English university. Awarded every third year	The Registrar, Canterbury University College, Christchurch, by 1 March
Royal Holloway College Scholarship	"	Royal Holloway College, University of London	"	2 years (may be extended to 3)	£150 p.a. (and £38 travelling allowances)	Restricted to graduates of Canterbury College who wish to take an honours or higher degree of the University of London. Suspended till further notice	The Board of Governors, Canterbury University College, Christchurch
Lord Rutherford Memorial Research Fellowship	Physics, chemistry or mathematics	Institution approved by selection committee	D.-D.	"	About £400 p.a.	Awarded every second year to graduates of the University of New Zealand or of any university of the British Empire who have resided in New Zealand for not less than 3 years. Suspended till after war	"
COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH:							
National Research Scholarships (4)	Science and industry	Unrestricted	"	1 year	£100 (allowance up to £25 for books apparatus, etc.)	Open to graduates of New Zealand University or other suitable persons approved by C.S.I.R.	—
NEW ZEALAND, UNIVERSITY OF:							
Engineering Travelling Scholarship	Engineering (mechanical, electrical, mining or metallurgical)	Abroad	"	"	£300	Restricted to junior graduates (B.E.) of the University of New Zealand	Registrar of the University of New Zealand and Registrar of candidate's College by 1 November

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
New Zealand, Univ. of—*contd.*:							
Post-Graduate Scholarships in Science (2)	Physics, chemistry botany, zoology or geology	University or institution approved by Senate	D.-D.	2 years	£300 p.a.	Restricted to graduates of New Zealand University (1st or 2nd class honours) of not more than 2 years' standing	Registrar, University New Zealand
Post-Graduate Scholarships in Arts (3)	Languages, mathematics, philosophy, economics, history or education	"	"	"	"	"	"
Medical Travelling Scholarship	Medicine	Europe or America	"	1 year	£300	Awarded on undergraduate work and results of University of New Zealand Bachelor of Medicine final examination	"
Travelling Scholarship in Dentistry	Dentistry	"	"	"	"	Awarded to Bachelors of Dental Surgery of University of New Zealand immediately after graduation on work throughout their course	"
Michael Hiatt Baker Scholarship	Unrestricted	University of Bristol	U.K.	1 year (may be renewed for second)	£200	Awarded to graduates of the University of New Zealand	"
Shirtcliffe Fellowship	Arts, science, law, commerce or agriculture	University or other institution in British Empire approved by Senate	D.-D.	2 years	£250 p.a.	"	The Registrar, University of New Zealand by 1 November
Shirtcliffe Research Scholarship	Arts, science, commerce or agriculture	University or other institution approved by Senate	"	1 year	£100	"	"
Otago, University of:							
New Zealand Obstetrical Society's Scholarship	Obstetrics or gynaecology	6 months at Women's Hospital, Melbourne, and 18 months in Europe or America	"	2 years	Not less than £150 p.a.	Candidates to have served at least 12 months as house surgeon after obtaining degree of M.B., Ch.B.	The Registrar, University of Otago

Auckland Travelling Scholarship in Obstetrics and Gynaecology	"	"	"	"	"	"	
Dunedin Savings Bank Scholarship in Dentistry	Dentistry	Any approved institution outside New Zealand	"	1 year	£35	Open to Bachelors of Dental Surgery of the University of New Zealand whose home on graduation is within 10 miles of Chief Post Office, Dunedin	
VICTORIA UNIVERSITY COLLEGE:							
Jacob Joseph Research Scholarships (2)	Law, experimental science, philosophy	Unrestricted	"	"	£60	Open to junior graduates who have completed an honours course	The Registrar, Victoria University College, Wellington

SOUTH AFRICA

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
ALL UNIVERSITIES OF THE UNION OF SOUTH AFRICA:							
Elsie Ballot Scholarships *	Unrestricted	Cambridge University	U.K.	2 years (may be extended to 3 years)	£300 p.a.	Open to unmarried candidates of European descent who have acquired by birth a domicile in the Union of South Africa. Age limit 19–25	The Trustees, Elsie Ballot Bursary Fund, P.O. Box 434, Pretoria
H. B. Webb Gift Research Scholarship	"	Unrestricted	D.-D.	2 years	£300 p.a.	The H. B. Webb Scholarship shall be available at each university every 5 years in the following order: Cape Town, Stellenbosch, South Africa, Witwatersrand, Pretoria	The Registrar of the candidate's university
UNIVERSITIES OF CAPE TOWN, SOUTH AFRICA, STELLENBOSCH AND WITWATERSRAND:							
Union Scholarships	"	"	"	"	£225 p.a.	Awarded on the results of the M.A. or M.Sc. examination. Age limit 25	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
UNIVERSITIES OF CAPE TOWN, SOUTH AFRICA AND STELLENBOSCH:							
Croll Memorial Scholarships	Unrestricted	Unrestricted	D.-D.	2 years	£225 p.a.	Age limit 30 years. Awarded on results of M.A. or M.Sc. (pure science) examinations but may be awarded to candidates for degrees of equivalent status in other faculties, on sufficient evidence of ability and promise. These scholarships are administered by the Joint Scholarships Committee, together with Union Scholarships. With the exception of the Queen Victoria Memorial they are assigned in rotation in such a way that on each occasion on which any award is to be made from a particular endowment three scholarships will be offered from that endowment, one of which shall be assigned to each of the Universities of South Africa, Cape Town, and Stellenbosch. The Committee provides that there shall not be fewer than two scholarships (irrespective of the Maynard) assigned annually to each of the above universities. The Queen Victoria Memorial is assigned in rotation to each of the above universities at three-yearly intervals and is open to women student only	The Registrar of the candidate's university
Donald Currie Memorial Scholarships	"	"	"	"	"		"
Ebden Scholarships	"	Cambridge University	U.K.	"	£300 p.a.		"
George Grey Memorial Scholarships	"	Unrestricted	D.-D.	"	£225 p.a.		"
Hiddingh Scholarships	"	"	"	3 years	£266, 13s. 4d. for 3 years		"
Porter Scholarships	"	"	"	2 years	£225 p.a.		"
Queen Victoria Memorial Scholarships *	"	"	"	3 years	£200 p.a.		"
Queen Victoria Scholarship	"	"	"	2 years	£225 p.a.		"
Maynard Scholarships (3)	"	"	"	"	£90 p.a.		

CAPE TOWN, UNIVERSITY OF:							
University Council Post-graduate Scholarships	Engineering or applied and industrial chemistry (2)	Any country overseas	D.-D.	2 years	£150 p.a.	Awarded on results of examinations for B.Sc. in engineering, applied and industrial chemistry, and surveying. Candidate must attain the standard required for distinction	The Registrar, University of Cape Town
"	Medicine (1)	"	"	1 year	£150 p.a.	Awarded on results of examinations for M.B., Ch.B., normally to candidates who obtain the degree with honours	"
Jamison Scholarship	Unrestricted	Unrestricted	"	2 years	£225 p.a.	Restricted to graduates born in Cape Province of parents domiciled there. Awarded on results of M.A. or M.Sc. examinations. Age limit 30	"
South African College Croll Scholarship			"	"	£300 p.a.	Open to graduates of the University of Cape Town, without distinction of creed, class or colour. Awarded on the results of the M.A. or M.Sc. examination. Age limit 30	"
Smartt Memorial Scholarship	Research in subjects or matters bearing upon agriculture	"	"	2 years (may be extended to 3 years)	£200 p.a.	—	—
C.S.I.R R	Research in natural, biological and engineering sciences and medicine	South Africa, but in special cases permission may be granted for tenure overseas	"	1 year (may be renewed)	£400–800 p.a. depending on circumstances	Open to holders of doctors degrees, who have proved their ability in research work, for research on specific projects	—
NMENT SCHOLARSHIPS:							
Agricultural Scholarship	Entomology	Overseas (others in agricultural subjects limited to U.S.A.)	"	Not exceeding 3 years	£300 p.a.	Open to graduates of the South African Faculties of Agriculture with major subjects of entomology and chemistry	Department of Agriculture, Pretoria; Department of Agriculture, Stellenbosch

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
PRETORIA, UNIVERSITY OF:							
George Ferrar Scholarship	Agriculture	Overseas	D.-D.	1 year (may be renewed)	£100 p.a.	Restricted to graduates in agriculture	The Registrar, University of Pretoria
SOUTH AFRICA, UNIVERSITY OF:							
Travelling Scholarships (Grey University College) (4 or 5)	3 for agriculture	Abroad	„	3 years	£150 p.a.	Holders must undertake, if required, to serve the Government upon their return for a period of at least 3 years	Union Department of Education, Union Buildings, Pretoria
Hiddingh-Currie Memorial Scholarship	Unrestricted	Unrestricted	„	„	£200 p.a.	Open to candidates with Master's degree in any faculty of the University	„
STELLENBOSCH, UNIVERSITY OF:							
Abe Bailey Scholarships	„	Oxford or any other British University	U.K.	„	£300 p.a.	Restricted to graduates (M.A., M.Sc. *cum laude*) of Stellenbosch University	The Registrar, University of Stellenbosch
WITWATERSRAND, UNIVERSITY OF:							
Chamber of Mines Research Scholarship	Mining and metallurgical practice (as affecting South Africa)	Unrestricted	D.-D.	1 year	£500 and a Gold Medal	Restricted to graduates who have attended 2nd, 3rd and 4th year courses for degree in mining and metallurgy at the university and have obtained distinction. Holder must undertake to practise in the Transvaal for 2 or 3 years after the research	The Registrar, University of the Witwatersrand, Johannesburg
Pioneer Women Scholarship *	Unrestricted	„	„	„	£60	Restricted to women graduates of Witwatersrand who are descendants of 1889 Pioneers	„
Adolph Wagner Scholarship	Engineering	„	„	1 year but may be extended in special cases for second year	£150	Awarded annually to the most distinguished graduates in mining or some other branch of engineering	„

Erleigh Scholarships (2)	(*a*) Research in meteorology (*b*) Research on, or related to, malaria	"	"	1 year (may be extended to 2)	£100–200 p.a. each, value determined by needs of the scholar and value of work	Open to graduates of the University of not more than 3 years standing (*a*) graduate in science (*b*) graduate in science or medicine	"
Mellor Fellowship	Research in bio-chemistry or bio-physics	Not stated	Not stated	1 year (may be extended)	£150 p.a.	—	"
University Council Postgraduate Scholarship	Unrestricted	Unrestricted	—	2 years	£225 p.a.	—	—
Council of Education Post-graduate Scholarship	Science, engineering, medicine, architecture or dentistry	Not stated	—	"	£250 p.a.	Open to graduates who have been registered students of the University for at least 3 years. Age limit 26 years	—

INDIA

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
BENARES HINDU UNIVERSITY:							
Holkar Fellowships (3)	One each in faculties of art, science, and technology	Abroad	D.-D.	1 year (may be renewed for second year	Rs. 3000 p.a.	Open to students of the Benares Hindu University and the junior members of the University teaching staff who have put in at least 5 years' service if they are not graduates of the University	The Registrar, Benares Hindu University
Shankar Lakshami Scholarship	Scientific, technical or commercial education	A foreign university	"	3 years (may be extended)	Annual interest on the endowment	Restricted to graduates of the Kayastha Community who have either taken a degree of the Benares Hindu University, or pursued a course of study or research for at least 1 year in the post-graduate department of the university	"

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application
BOMBAY, UNIVERSITY OF:							
Eduljee Dinshaw Scholarship	Technology	Abroad	D.-D.	3 years (may be extended)	Rs. 400 per month	Restricted to graduates of Indian Universities (M.E., M.Ag., M.Sc., M.Sc. (Agri.), M.Sc. (Tech.)) of not more than 10 years' standing who are members of the Parsi community professing Zoroastrianism. Preference to residents of certain specified areas	The Registrar, University of Bombay
Mangaldas Nathubhai Travelling Fellowship	,,	Europe	U.K.	3 years	Rs. 700 p.a.	Open to Hindu graduates of the University of not more than 5 years' standing	,,
Sir Currimbhoy Ebrahim and Bai Khanoobai Noormahomed Jairazbhoy Peerbhoy Scholarships (3)	Medicine, philology, ancient history, Arabic, architecture, town - planning, technological and industrial subjects, economics	Abroad	D.-D.	3 years (may be extended up to maximum of 5 years)	Rs. 3600 p.a. each	Scholarship loans available for Mahomedan graduates of the university of not more than 7 years' standing. Restricted to bona fide natives of the Presidency of Bombay	,,
Sir Mangaldas Nathubhai Technical Scholarships (2 every year, and an additional one every third year)	Technology	England	U.K.	,,	Rs. 2000 p.a. each	Open to Hindu graduates of the University	,,
Sardar Bhimrao Ramrao Akbarnawis Research Scholarship	Mathematics, science, engineering, agriculture, technology, medicine, or surgery	Europe or America	D.-D.	3 years	Rs. 2400 p.a.	Restricted to Brahmins from the districts of Belgaum and Dharwar and the states of Kolhapur and Sangli, who have passed the M.A. examination in mathematics or M.Sc., M.E., M.Ag., M.Sc. (Agri.), M.Sc. (Tech.), M.D. or M.S. examinations of the University	,,
CALCUTTA, UNIVERSITY OF:							
Government (State) Scholarships (2)	Unrestricted	United Kingdom	U.K.	,,	£215–355 p.a. each	Awarded in alternate years to the best Hindu and Mahomedan candidates from the universities of Bengal	The Registrar, University of Calcutta

Guruprasanna Ghosh Scholarship	Arts, sciences or industries	Europe or America	D.-D.	"	Rs. 2000 p.a.	One awarded annually to natives of Bengal. Preference to Hindus	"
Sir Rashbehar Ghosh Travelling Fellowships (3)	Education (1), Scientific research (2)	Abroad	"	1 year	Rs. 4400	Open to graduates of the University of Calcutta	
Radhikamohan Scholarships (6)	Applied and industrial science	Europe, Asia and America	"	2 years	Rs. 5000 and passage	Open to Bengalee Brahmin graduates with previous training in mechanical engineering, or in chemical or other technical industry existing in the country, or in agriculture	
Sir Taraknath Palit Scholarship	Science	Unrestricted	"	Duration variable	Interest on a sum of Rs. 1,00,000	Scholarship loans available for unmarried graduates of Calcutta University (M.Sc. and D.Sc.) who know the language of the country they wish to visit	
Lalchand Moolerjee Scholarships	Theoretical and practical training	Abroad	"	—	Rs. 1,50,000 capital	—	
MYSORE, UNIVERSITY OF:							
H.H. the Yuvarani Sri Kempu Cheluvajammanniavaru Foreign Scholarship *	Higher medical studies to specialize in diseases of women and children	Europe or America	"	—	Rs. 300 per month	To the most deserving lady medical graduate of Mysore University with at least 1 year's practical clinical experience after graduation or the most deserving lady medical officer who has served in the Mysore medical department for at least 1 year	The Registrar, University of Mysore
Damodardas Scholarships (2)	Preference to a branch of science	"	"	2 years (may be extended to 3 years)	£250–£300 p.a.	Open to outstanding graduates of Mysore University	"
Government Scholarships (2)	"	"	"	"	"	"	"
NAGPUR, UNIVERSITY OF:							
Post-Graduate Research Scholarship	Science	Unrestricted	"	2 years (may be extended)	Rs. 100 per month	Restricted to graduates in mathematics who are residents of Nagpur Province	The Registrar, University of Nagpur

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
OSMANIA UNIVERSITY:							
Hyderabad State Fellowships (21)	—	England and America	D.-D.	—	—	—	The Vice-Chancellor, Osmania University, Hyderabad, Deccan
ANJAB, UNIVERSITY OF THE:							
State Scholarships	Unrestricted	United Kingdom	U.K.	2 years	£300 p.a. when held at Oxford or Cambridge; at universities other than these £250 p.a.; £300 p.a. to women scholars	Open to graduates of the University of the Panjab (M.A. or M.Sc., B.A. or B.Sc., M.Sc.(Ag.), B.Sc.(Ag.) and B.Com.	The Registrar, University of the Panjab
PATNA UNIVERSITY:							
University Scholarship	"	"	"	"	"	Open to graduates of Patna University (M.A. or M.Sc., B.A. or B.Sc. with honours) who are statutory natives of India. Age limit 22–25	—

EIRE

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
DUBLIN UNIVERSITY OF:							
Trinity College— *John Winthrop Hackett Prize*	Science subjects	Abroad	D.-D.	1 year	£100	Restricted to graduates of special distinction	The Registrar, Trinity College, Dublin
Moderatorship Prizes	Unrestricted	Abroad in case of modern languages, otherwise unrestricted	"	"	About £50	"	"
Harmsworth Exhibition	"	Unrestricted	"	"	£100	Restricted to graduates	"
Other Prizes for Research	Medicine or surgery	Institution other than Trinity College	"	"	Various	Restricted to medical graduates	"

NATIONAL UNIVERSITY OF IRELAND:							
Travelling Studentships (5)	1 in anatomy, physiology or pathology; others unrestricted	Universities of Britain, Europe and U.S.A.	U.K.	2 years	£300 p.a.	Open to graduates of the university of not more than 4 years' standing (not more than 2 years for the medical studentship)	The Registrar, National University of Ireland, Dublin
Dr H. H. Stewart Scholarship	Mental and nervous diseases	Recognized institutions for nervous diseases	D.-D.	3 years	£50 p.a.	Restricted to medical graduates of the university of not more than 2 years' standing	"

BURMA

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
UNIVERSITY OF RANGOON, BURMA:							
Scholarships	Advanced study in Epidemiology, tuberculosis, etc.	United Kingdom	U.K.	—	—	—	The Registrar, University of Rangoon

CEYLON

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
CEYLON, UNIVERSITY OF:							
Ceylon Government Scholarships (4)	One each in arts, science, mathematics and oriental languages	United Kingdom	U.K.	2 years with possible extension	£360 p.a. for collegiate residence in Oxford or Cambridge or £325 non-collegiate residence at Oxford and Cambridge. Otherwise £240 p.a. Medical allowance £50. Fees to Director of Colonial Scholars £3 each p.a. Passage allowance to England Rs. 1200 each journey. Outfit allowance Rs. 750	Awarded to students of the University of Ceylon on the results of the final examinations of the University of London	The Registrar, University of Ceylon, Colombo

MALTA

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
MALTA, UNIVERSITY OF:							
Graduate Travelling Scholarships (4)	1 theology 1 law 1 engineering and architecture 1 medicine and surgery	Abroad	D.-D.	1 year	£120 each	Restricted to candidates who have passed annual examinations in first session with highest marks, and are recommended by the Faculty concerned	The Secretary, University of Malta
Lorenzo Gatt Scholarship	—	—	"		£5c	Awarded every 3 years to student who is awarded Graduate Travelling Scholarship in Engineering	"

SINGAPORE

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
RAFFLES COLLEGE, SINGAPORE							
Post-Graduate Scholarship	—	United Kingdom	U.K.	2 years	£500 p.a.	Student of Chinese race or descent. In suspense pending reconstitution	—

INTERNATIONAL

University or Institute, etc.	Subject.	Where Tenable.	Class.	Duration.	Value.	Remarks.	Application to:
AMERICAN ASSOCIATION OF UNIVERSITY WOMEN:							
International Fellowship *	Research unrestricted	Some country other than the holder's own	D.-D.	Duration not stated	$1500	Open to graduates who are members of a national association or federation of university women and who are nominated by their own association	Applications through the British Federation of University Women, 17A King's Road, London, S.W.3
INTERNATIONAL FEDERATION OF UNIVERSITY WOMEN:							
Fellowship *	Alternately arts and science	"	"	1 year	£300	"	"

METHODS FOR IMPROVING THE INTERCHANGE OF SCIENTISTS THROUGHOUT THE EMPIRE. INCLUDING A DISCUSSION ON THE FUTURE OF THE SCIENTIFIC LIAISON OFFICES

By Sir DAVID RIVETT, K.C.M.G., F.R.S.
(Chairman, Council for Scientific and Industrial Research, Australia)

IN any consideration of the scientific liaison offices which Australia established in London and Washington during the war it should be borne in mind that the purpose in each was quite specific. The first office was in London, brought into being in 1940 in order to facilitate the flow of information regarding developments in the technique of radio-location (radar) from the United Kingdom to Australia. The Commonwealth Radiophysics Laboratory in Sydney was in its infancy and the flow of knowledge was all in one direction—outwards from the United Kingdom. When, as was inevitable, interest moved more towards general apparatus and actual working instruments, it was to the United States of America that it became necessary to look in order to obtain Australia's requirements. An office was therefore opened in Washington and its main business, or at any rate its main difficulty, was associated with the procurement of supplies.

Both offices were thus brought into existence to meet the needs of Australian war work in one particular main line—radiophysics. As time went on, however, the men in these offices (almost all of them physicists) were called upon to extend their interests and inquiries. They became, perforce, 'jacks of many trades' other than their own. The need for this arose not only from the fact that the normal flow of information, which in peace-time was through scientific periodicals and journals, had largely ceased, but also because Australia required knowledge very much in advance of the stage at which it might, even without the war-time shroud of secrecy, have been publishable.

It was, however, recognized (and this is an important fact) that a small staff of men, however able in their individual lines, could not possibly keep in touch with what one may term the front lines of investigation in a diversity of subjects, either in the country in which they resided or in their home land. This meant that where information was required at a high original research level there was nothing for it but to send from Australia the leading workers at that level to meet and discuss their problems personally with their opposite numbers in the United States of America, United Kingdom or other Dominions. In other words liaison offices, it was early realized, could not be expected greatly to affect the need for short visits by research men of the front line desiring to see for themselves just how their problems were being viewed and tackled elsewhere. Personal contact between actual workers in highly specialized and advanced lines cannot be replaced by bridge-making through intermediaries.

If we in the scattered British Commonwealth are to make the most of our resources in men, money and in some cases materials, each must take full advantage of the facilities possessed by the other. The team's effort can add something to the total contribution of the individual acting alone. One need not lay particular emphasis upon the wisdom of avoiding overlapping and repetition. A measure of each may be very desirable, though excess of either is waste. It is the stimulus that comes from tête-à-tête discussion that counts, and this is what we must strive to increase.

Naturally we in the distant Dominions feel the need for such contacts more than you do in the United Kingdom and Canada, particularly perhaps in the physical sciences. Movement therefore tends to be rather uni-directional at present; but I venture to predict that time will bring about a rapid increase in realization of the value of scientific traffic amongst workers from and to every section of the Commonwealth.

The word 'interchange' is used in the title to this discussion, but I take it that no one nowadays would argue in favour of an exchange of actual positions between two men in different lands. If a man from one country A takes over the duties of an opposite number in country B, he may find all expected advantage to have been illusory. There must be no tying-down of anyone in unfamiliar surroundings to the particular bread-and-butter duties of someone else; that way lies little but disappointment. Every traveller must be given complete freedom to wander at large when in another's territory. I am speaking of course of senior men, not of students or young graduates.

The essential item is only too obvious—quick, cheap travel. Some of us expect before long to reach London 60 hours after leaving Sydney. The problem of sufficiently quick movement has therefore been solved. A three months' vacation from Australia can now mean eleven weeks in England; not long ago one was lucky if it meant a fortnight. But the cost? The £750 which must be paid to transport one Australian body to and fro is a big sum to the scientific mind and budget. Maybe the commercial companies will cut it to one-half before long, with bigger planes and more passengers to each one of them. But it will still remain a big figure, at least until our next Conference. I see nothing for it but for every C.S.I.R., D.S.I.R., N.R.C. or what-not to include in its budget a sum for travelling far in excess of anything we have provided in the past; and this we intend to do in Australia. It is as reasonable a cost as any other in a laboratory's annual expenditure. Is it, however, impossible to secure help from other quarters? Would it, for example, be impracticable for the Royal Society to operate a couple of large aeroplanes presented to it (and even endowed) by a public-spirited manufacturer 'for the interchange of scientists throughout the Empire' and provided by all Empire units, free of charge, with necessary landing ground facilities? It is perhaps worth further consideration.

There may of course in some places be Trust Funds or Foundations or Bequests from which expenses of travelling may be voted to particular individuals. These will be all to the good, but we should not regard this as a main approach to the problem. We should each be prepared to budget for travelling just as we do for chemicals and apparatus.

Returning now to the liaison offices, I would again point out that their

usefulness is limited just because they cannot possibly be 'omni-scientific.' It is fatally easy to expect too much of them, and it is just as fatally easy for the individuals in them to attempt more than they can achieve. A small office, acting as a clearing house for reports, etc., and with the local knowledge that will facilitate movements of travelling specialists and save much of their time, will be useful and indeed is essential. We in Australia desire only that its limitations be kept in mind and that it be not allowed to cloud the view of the pressing need for effecting liaison by direct contact between front-line investigators themselves.

The advantages of a British Commonwealth Scientific Office in a particular centre are those of any other example of team work, though it will be advisable in practice to ensure that centralization does not lead to the loss of certain other advantages resulting from the scattering of units. Another practical matter is cost. Within the Empire estimation is easier than in, say, the United States of America. Roughly speaking it costs Australia three times as much to maintain an officer in Washington as it does to keep him in his own country on work at the same level. Empire preference seems to be indicated.

There is one last point : should liaison offices, either within or without the Empire, be officially associated with political embassies, legations, etc. ? Views may differ but, broadly speaking, we shall probably all agree that avoidance of any apparent, let alone real, political association or control is the course of wisdom.

MEMORANDUM ON THE MOVEMENT OF SCIENTISTS THROUGHOUT THE EMPIRE

By Professor B. F. J. SCHONLAND, C.B.E., F.R.S.

1. *Movement of research workers*

The position in regard to this matter from the South African point of view is that machinery for visits by *research workers in the government service* to other countries exists, though the granting of special study or research leave is a difficult matter and will require further attention on the part of the Government if a satisfactory scheme is to be evolved.

Research workers in universities and others not in government service will be looked after by the newly-formed C.S.I.R. which may shortly consider a travelling fellowship scheme to supplement its scheme for research fellowships in South African Universities.

2. It is suggested that the Councils for Scientific and Industrial Research in the Dominions and the D.S.I.R., M.R.C. and A.R.C. and Colonial Research Council in Great Britain should be the bodies to *co-ordinate research collaboration* in the Commonwealth and be given powers to arrange this. In cases where their fields are not wide enough they should co-opt representatives of other bodies covering those fields. A first step forward would be obtained if such bodies agreed to create *Commonwealth Research Fellowships* in certain fields, to be held by scientists from other parts of the Commonwealth.

3. Through the bodies suggested in paragraph 2, arrangements should be made for

(*a*) periodic conferences of a specialized character ;
(*b*) reduced air and other travel charges for such conferences ;
(*c*) visits by leaders in particular fields of work ;
(*d*) information services of an improved kind ;
(*e*) the training of technicians for service in adjoining colonies and protectorates.

4. *Information*

The South African C.S.I.R. is proceeding to set up an extensive scientific and technical *information bureau* for scientists, industrialists and government departments with missions initially in London and Washington. The Department of Commerce and Industries will work in with this bureau by attaching officers abroad with a view to studying the economic aspects of new developments.

It is felt that steps should be taken

(*a*) to examine what *new services of information* and technical news digests are required ;

(*b*) to create '*pools of information*' to which research officers of the Commonwealth would contribute ;

(*c*) to create a *Commonwealth microfilm organization* ;

(*d*) to examine what can be done to develop the *circulation of scientific films* illustrating new scientific developments for industry, education and research ;

(*e*) to publish *scientists' guides* for technical and scientific officers visiting any part of the world.

5. Of special interest to South Africa is the development of a *co-ordinated regional scheme* of research in Africa. In the first instance, this should be developed as a scheme covering the Union and the British territories to the North. When appropriate, scientists from adjoining non-British territories might be invited to join in discussions or conferences on special problems of mutual concern. It is felt that this is the most important area for regional research in the Commonwealth and Empire. The subjects which might be regionalized in the first instance, are

1. veterinary research
2. agricultural research
3. systematic botany and ecology
4. plant physiology
5. entomology
6. insect physiology and insecticides
7. geology
8. geophysics
9. meteorology
10. forestry and forest products research
11. geochemistry
12. nutrition and environmental medicine
13. tropical diseases
14. building research

It is suggested that the best way to start such a regional plan would be to create *in Africa* a few central institutes, on the lines of the Imperial Agricultural Bureaux. These institutes would vary according to the subject and its state of development but could be roughly classified as :

(*a*) *Long-range research institutes* with highly specialized staff and equipment.

Examples : plant physiology
insect Physiology
geophysics
meteorology
geochemistry
tropical diseases :

(*b*) *Institutes of a museum character*, with type specimens and a unique library of information.

Examples : entomology
ecology and systematic botany

(*c*) *Co-ordinating centres associated with laboratories.*

veterinary research
veterinary agricultural research
geological surveys
geophysics
forestry and forest products
nutrition and environmental medicine
tropical diseases
building research

6. The South African Government is in favour of a wide extension of the conception of scientific missions both for the securing of information and for the co-ordination of Commonwealth and later of international seientific effort. It will gladly co-operate in any proposals for joint action including the housing of all missions in one building.

TRAVEL GRANTS AND FACILITIES FOR VISITS BY SCIENTIFIC OFFICERS, IN SOUTH AFRICA

By Professor B. F. J. Schonland, C.B.E., F.R.S., South Africa

The position in the Union of South Africa is as follows :—

1. *Government departments*

Scientific officers in the employment of the South African Government are permitted to travel and reside overseas to undertake specific research work or to gain experience under the following conditions :—

(*a*) If the visits are of the character of tours for the inspection of research and other institutions overseas or attendance at conferences or for the securing of special information for the department concerned, the Government pays all expenses and special allowances to cover the additional costs to the officer.

(*b*) If the visits are for the purpose of study, investigation, consultation or research at the instance of the department concerned in relation to local problems of urgency and importance, the same arrangements hold. In such a case the governing factor is whether the visit is mainly in the interests of the State and if this is the case the fact that the officer acquires specialist training and experience of direct or indirect advantage to himself does not affect the decision to pay all his expenses. In this case, as in (*a*) above, the seniority of the officer in the service and his pension rights are not interfered with. In general, however, it is not usual for cases to be agreed to under heading (*b*) if the duration of the visit is longer than a year.

(*c*) Visits for study or research directed to investigations which, while desirable, are not essential in departmental interests. Here the Government's attitude is that it will grant special leave on full pay for a portion of the absence of the officer, the remainder having to be made up by the accumulated vacation leave of the officer concerned. Absence in this case does not affect seniority or pension rights.

(*d*) Study leave, i.e. courses of advanced study, investigation or research related to the official duties of the officer but not necessarily initiated by the department. Here again, the Government is prepared to consider special leave on full pay for part of the period involved. If the officer has not sufficient accumulated leave to cover the remainder of the period, he may be granted leave without pay. In such circumstances he would be required to defray the Government's pound for pound contribution to the pension fund for this leave-without-pay period, but his subsequent salary and seniority are not affected.

(*e*) Long-term courses of approved subsidized study to furnish the officer with special experience or training. No special facilities are granted for this purpose and in general the officer concerned would have to obtain his financial support from a Government scholarship or a Commonwealth fellowship. The officer is permitted to utilize vacation leave to his credit and the balance of the absence will be covered by leave without pay which would not adversely affect his salary or seniority on resumption of duty. He would be called upon to pay the Government portion of the contribution to his pension fund.

It will be seen that the machinery for the purpose is both adequate and reasonable. In the operation of the machinery there are naturally two points of view. The scientific officers are anxious to take as many opportunities as they can for overseas travel and research while the Government, as represented by the Secretaries of departments and the Public Service Commission, have to consider the difficulties which would be caused by prolonged absences and the value which such visits would have to the department itself.

2. *The Council for Scientific and Industrial Research*

In terms of its regulations, the C.S.I.R. can give special leave with pay, without pay or with part pay, to such of its officers whose visits overseas for research and study would be in the interest of the Council. Officers coming under this category must undertake to remain in the Council's service for a period of at least three years on their return or refund the cost of sending them overseas and any special allowances. The detailed machinery for this purpose has not yet been worked out, but it is anticipated that junior officers, who are sent over for special study will not be granted special allowances while overseas. The C.S.I.R. would have freedom to make such arrangements with regard to the interchange of officers with other organizations as it thinks fit. In all such cases the pension rights and seniority of the officers concerned are maintained.

3. *Universities*

While there is some variation between different universities, the general position is that sabbatical leave is granted every six years. The universities give three months on full pay and three months on half-pay. On occasion they grant longer periods of leave without pay. Under an arrangement now being worked out between the C.S.I.R. and the universities, whereby research fellowships can be awarded to investigators of outstanding ability, it is possible for such fellowships to be held overseas in special cases. No experience exists of the working of this machinery and it is not at present likely that there will be many such cases. The principle, however, has been agreed to and, if the need arises, the system can be further developed.

Special cases

The *Post Office* has a system of special overseas visits of its technical officers at regular intervals. It maintains liaison arrangements with the British and Australian Post Offices and with the American telephone and

telegraph companies. The *meteorological services* of the Union have an arrangement for temporary transfer of their officers to the services of other Dominions and to those of the United Kingdom. In such cases, the travel expenses are paid by the South African Government and the salaries of the officers during their absence are met by the country in which they are temporarily serving. Four such officers had been sent to Britain and the Dominions, for about a year in each case, up to the outbreak of the last war.

The South African Institute for Medical Research has a system of study leave on full pay for its officers. This has been of limited application on account of the shortage of funds.

The Bernard Price Institute of Geophysical Research, University of the Witwatersrand, will grant study and research leave on full pay to officers proceeding overseas in the interests of the Institute. Owing to the war no cases have yet occurred. The Institute has also a 'Guest Research' fund to enable it to pay the expenses of a short visit of an overseas scientist of distinction. The sum involved is about £150 and is available at least every two years. The only 'Guest Researcher' in the short time the Institute was operating before it was transferred to military service, was Dr. E. Bullard, of the University of Cambridge, who spent some three months at the Institute. This particular type of visit is regarded as of special value.

MORNING SUBJECT (g)

DISCUSSION OF EMPIRE CO-OPERATION IN THE SCIENTIFIC FIELD WITH EXISTING AND PROJECTED INTERNATIONAL ORGANIZATIONS

Steering Group

Chairman—Professor A. V. Hill, For. Sec. R.S.

Recorder—Professor F. J. M. Stratton

Sir Shanti Bhatnagar, F.R.S.
Mr J. C. Eyre
Dr Alexander King
Dr C. J. Mackenzie
Sir Theodore Rigg
Sir David Rivett, F.R.S.
Professor B. F. J. Schonland, F.R.S.
Sir Henry Tizard, F.R.S.

Report

It was fitting that the discussion of this subject should be held at the penultimate session of the Conference after the outstanding problems of the British Commonwealth had received attention.

As an introduction to the discussion the methods of the functioning of various international scientific unions were described and delegates listened to an account of the plans for science which the Preparatory Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO) was considering.

Delegates were enthusiastic on the subject of international scientific co-operation and strong conviction as to its importance for the prevention of war and the welfare of mankind was evident. Nevertheless, fears were expressed by some delegates that international scientific organizations might be set up without the full agreement of the scientific bodies concerned and be harmful to the free progress of science. It was also feared that in the future as in the past organizations set up under international authority might persist in their activities after they had outlived their usefulness.

It was agreed that each delegation should advise its government to adhere to the various International Scientific Unions such as those on chemistry, geodesy and geophysics, astronomy, etc. While the proposal was welcomed that UNESCO should help to finance certain scientific projects of the unions, the Conference strongly expressed the view that the work of such organizations could only prosper if control remained with the scientists themselves. Each delegation, however, agreed to advise its government and the scientific institutions in its own country to collaborate closely with UNESCO and other organizations of the United Nations concerned with the promotion of science and its applications.

It was considered that scientists in the Colonies should be directly associated with international scientific activities. The policy already initiated by the Secretary of State for the Colonies of appointing a scientist in each territory, to act as a centre for communication on scientific topics with the official scientific organizations in the United Kingdom, should also allow as far as possible of their making direct contact on scientific matters with international organizations.

Recommendations

1. The Conference recommends that the delegations should advise their governments to adhere to each of the International Scientific Unions, to the International Council of Scientific Unions and to other recognized international scientific organizations.
2. The Conference recommends that scientific correspondents be appointed in Colonial territories to establish and maintain direct contact in scientific matters with the operational agencies of the United Nations and with other recognized international bodies.
3. The Conference would heartily welcome a policy on the part of the United Nations and its operating agencies to make the utmost use of all scientific bodies which are doing valuable work of an international scientific character and would stress the importance of preserving the independence of such bodies and of leaving the control of their activities to scientific men.
4. The Conference recommends that each delegation should advise its government and the established scientific institutions of its country to collaborate closely with any organization of the United Nations concerned with the promotion of science and its applications.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr E. Marsden

Dr Marsden stated that he wished to support the remarks and points of view put forward by Sir Henry Dale and Sir David Rivett.

In the Charter drawn up at San Francisco there was no specific reference to international collaboration in science. In his opinion there was a fundamental omission as, if scientific information and facts could flow freely across national borders, less suspicions and differences would arise between countries. At a later date the S was inserted in UNESCO, but not sufficiently prominently to affect representation. We needed more democracy in the international organizations from the point of view of selection of national representation and to build up from below.

The New Zealand Delegation, particularly the New Zealand people and the New Zealand Government, were keenly in support of international organizations of co-operation, and particularly the helping of less favoured countries and peoples to achieve peaceful conditions and higher standards of living. Consequently they were in support of UNESCO, but, personally, he hoped that the idea of free exchange of scientific information would be the first objective rather than grandiose schemes involving undue interference with local or group initiative and effort.

Regarding the resolutions before the meeting, he doubted whether we were justified in specific reference to the Secretary of State for the Colonies as envisaged in resolution 2. Regarding resolution 4 he would prefer it to stop at the words ' scientific affairs ' in line 3 ; also that scientific societies and institutions should be included as well as governments.

Sir David Rivett

Sir David Rivett (Australia), confessing to some diffidence in approaching this subject, suggested that one should look to past history for guidance. After World War I there was a wave of enthusiasm for internationalism which, in scientific circles, expressed itself in the setting up of an International Research Council with branches in most countries and, shortly afterwards, in the creation of a number of international scientific unions. Some of these had done good work. Sir Harold Spencer-Jones had outlined the activities of one of them, but it was a mistake to regard the Astronomical Union as typical ; it was, on the contrary, very successful. The majority had been disappointing, at any rate as viewed from a distant part of the Commonwealth. The factor of leadership, inevitably associated in any particular case with the location of a union's headquartes, largely determined subsequent history and could not be overlooked. It might be

of interest to compare results in those cases where British or American or Scandinavian influence was dominant with those where the main responsibility had been placed on other shoulders.

It was now proposed that in certain of its scientific enterprises, UNESCO should build upon the foundations of these international unions. He questioned the wisdom of the plan until UNESCO had proved its capacity to maintain such a structure and to provide it with the freedom and fresh air needed for its development. The ideas of the Preparatory Commission were very big, but to bind the success of international scientific effort to an untried and rather grandiose scheme for an organization, with headquarters in Paris, seemed in the light of experience to be taking an undue risk. If UNESCO flourished it would draw other international agencies towards itself; if it failed, it would be sad to see it carry down with itself such scientific agencies as had proved their capacity for independent existence when given the right leadership. He urged caution in the approach to the ideas of the architects of UNESCO.

With regard to the matter of appointment of scientific attaches to political legations and embassies, he questioned the wisdom of the association. Any apparent political association, even if far from real, might be a handicap to a man whose task was to secure the friendship and cooperation of scientists only as fellow searchers for knowledge, sharing his acceptance of the basic principles upon which alone such search should be conducted.

EMPIRE CO-OPERATION IN THE SCIENTIFIC FIELD WITH EXISTING AND PROJECTED INTERNATIONAL ORGANIZATIONS

By Sir SHANTI BHATNAGAR, O.B.E., F.R.S. and D. N. WADIA, M.A.

SCIENTIFIC progress among the different units of the British Commonwealth has now reached a stage where measures of close collaboration could be most usefully undertaken. From the reports of the success of the British Commonwealth Scientific Office in Washington and the scientific liaison offices in London in promoting intensive co-operative teamwork in scientific research, there should be no doubts left now of the advantages of continuing such collaboration.

The instinct of self-preservation which prompted the United Nations and particularly the U.K. and U.S.A. to collaborate in war-time research should now be elevated to the higher and nobler plane of concerted human endeavour to harness science to the utmost for the good of mankind through co-operative pooling of resources. During the war considerable experience has been gained in this direction, and though India as such had not had the advantage of first-hand knowledge, still we are quite conscious of the achievements of that scientific collaboration. The world has suffered much through competitive organization of world industry and its intensively individualistic outlook in the economic field. The question then naturally arises, whether the scientists, too, are prepared blindfolded to follow the same rut and allow development of science on a model which may ultimately lead to utter destruction and annihilation. It would be fatal, indeed, if scientific achievement is ever allowed to become competitive in this sense. Some duplication of effort in fundamental science is unavoidable and, in fact, necessary for a healthy growth. But so long as the results obtained are freely discussed or published there ought to be no fear of a competitive spirit. Till recently science was allowed full freedom within the portals of universities and centres of research. Learned societies and scientific journals provided an accepted medium of exchange of information, which was supplemented whenever possible by personal contacts among individuals. Opportunities of free discussions at gatherings and interchange of publications promoted activity and stimulated thought. The growth of industry somewhat checked the scientists' freedom when research laboratories fostered by organized industries placed bans of secrecy on their staffs. Yet apart from actual processes no restriction operated even there against publication of results of fundamental work. This order of things first started to change shape ominously in Nazi Germany when university centres long associated with free scientific thinking were closed to foreigners and Jews. The last Great War demonstrated unmistakably the value of collaborative work. But it also showed how scientific men could be made pawns in a game of unparalleled destruction and how it is possible that all their cherished ideals of free growth of

science might be shattered to bits in the aftermath of nuclear disintegration. The fetters imposed on science in the name of security can never allow fulfilment of the co-operative ideal. Secrecy and distrust, for long the handmaidens of diplomatic services, should in no case be allowed to undermine the mind of the scientific worker. It is to further this spirit of the freedom for science that the Indian scientific men welcome the move of the Royal Society towards an Empire collaboration, and let us hope soon towards a world co-operation. We propose a scientific liaison staff from India stationed in London with adequate budgetary provision. The existing organizations of the Council of Scientific and Industrial Research and the National Institute of Sciences in India may be more fully utilized as India's representative in the United Nations' scientific, educational and cultural organizations. India has to-day over twenty-six scientific societies actively serving different branches of science. A live contact between these and their parallel numbers in Great Britain is still lacking. A discussion to explore ways and means of establishing fruitful liaison may take place between the representatives of these societies in Great Britain and the Indian delegates.

Coming to more concrete consideration of the machinery for co-operation within the Empire, much common ground has already been covered in the notes circulated by the Royal Society on the object and scope of the Conference. Before we discuss the actual machinery, we would suggest a discussion of two broad principles which appear to be basic for all future co-operation. The first principle to our mind is the recording of a general desire to share knowledge. Perhaps the very fact that we are all assembled here is a recognition of this principle. But let us be explicit about it. If the scientific knowledge which each unit of the Empire possesses could be readily exchanged a very considerable and futile overlapping of effort will be saved. Obviously, we shall be working here on the principle of *give* and *take* but it may also mean that in the initial stages there may be more *give* than *take* on the part of certain units and more *take* than *give* on the part of certain others. What is important is a tacit understanding that between the units of the Empire countries there shall be complete understanding on this basic principle. In practice it is not intended to give a feeling of dependence on knowledge acquired from other units nor is it intended that it should lead to relaxing of efforts by individual units for the advancement of science.

The second principle depends on the acceptance of the first and it is that in the matter of trade exploitation of any process about which information is furnished by another country there shall be mutual agreement on the terms and the extent to which exploitation will be permissible. The underlying idea should be that those processes for which most advantageous facilities exist in any participating unit should be encouraged there rather than elsewhere. In practice this principle may lead to a consideration of the present machinery for patents and their exploitation. It may also require consideration as to how far the purchase of patents by cartels interested only in suppressing the growth of new processes to safeguard their own interests should be permitted. If these two principles could be accepted and machinery set up to implement these, there can be no two opinions about the acceptance of the measures for co-ordination

and co-operation suggested in the Royal Society notes. The first necessity in this connexion will be permanent liaison offices. The details of these offices is to form the subject matter of a separate discussion but we may perhaps work on the assumption that they will not only continue but would be strengthened by the inclusion of other units. In a way, these liaison offices should be for scientific men what diplomatic offices are for the state. They should be the normal channels for all measures of scientific co-ordination and co-operation within the Commonwealth. This should not mean that the present individual contacts between individual workers would in any way be affected. In fact, the agency of liaison offices should provide new and ready means for establishing fresh contacts.

The basis of intercourse among scientists needs to be considerably widened. Improvement of facilities for interchange and dissemination of results of research are to form the subject matter of a separate discussion. We may, however, point out here in a general way that interchange should be extended beyond periodicals and reprints, to include materials, specimens, facilities for experimentation and research between different countries. It may be appreciated that India and the countries on the Pacific border and those in the equatorial desert zone will have much to offer in this respect from their varied agricultural, forest and mineral resources. On the other hand, India will still have to depend on others in physical, chemical and technological fields.

Perhaps one of the biggest assets in promotion of collaboration will be extension of facilities of personal contacts between scientific workers themselves. Such contacts have in the past been limited either to the older scientists or to raw students going abroad for degrees. The claims of the men in the universities and others who are actively engaged in laboratory work and who are the most likely to gain by contacts have often been overlooked. Such visits should be encouraged and some machinery may be devised for the purpose. The question of financing such visits is an important one and deserves to be examined with a view to making concrete suggestions.

In the field of international co-operation there is already in existence an International Council of Scientific Unions. The International Scientific Unions established under its auspices have already achieved considerable success in several subjects needing international agreement. The achievements of these Unions should receive wider recognition. India should become a permanent member of the International Scientific Unions, particularly the Unions of Geophysics, Geodesy and Isostasy, Oceanography, Radio and Ionospheric research. International collaboration is most needed in these borderline sciences and it is possible for India, from her geographical position and features, to make some positive contributions to these sciences in course of time.

The formation of a National Union of Geodesy and Geophysics in India is soon to be taken up by the National Institute of Sciences of India. This is to be affiliated to the International Union of Geodesy and Geophysics. The Gravity Survey of India with its last eighty years of geodetic investigations and the magnetic observations of the last hundred years of the Colaba Observatory and of the Travancore Observatory, will supply the nucleus. By such affiliation India can effectively implement the

resolutions passed at the Lisbon meeting of the International Union of Geodesy and Geophysics in September 1933, expressing its keen desire for the resumption of the valuable work on terrestrial magnetism of the Trivandrum Observatory, situated close to the magnetic equator. Such a Union can help materially the work of the Geodetic Survey in bringing to light important data on the isostatic equilibrium of the earth's crust—a branch of science which originated in India in 1856 and one in which the structural framework of India has yet to reveal much new knowledge on the physics of the crust.

The more recent organization, the United Nations Educational, Scientific and Cultural Organization may perhaps be developed into a central body for international collaboration. In this connexion the suggestion that the principles of scientific collaboration in international spheres should be incorporated in the constitution of the United Nations Organizations deserves to be seriously considered. Unless this is done there can be no hope of freedom of science from secrecy and political control. It may be expected that a strong Commonwealth scientific organization would go a long way towards paving the way for international co-operation.

EMPIRE CO-OPERATION IN THE SCIENTIFIC FIELD WITH EXISTING AND PROJECTED INTERNATIONAL ORGANIZATIONS

By D. Cairns, M.Sc.

New Zealand's co-operation in the scientific field with existing and projected international organizations cannot be fully determined until the ultimate form of some of the United Nations committees and orders of reference have been determined.

The organizations considered in this paper are as follows :—

1. U.N. Food & Agricultural Organization (UNFAO)
2. U.N. Educational, Scientific & Cultural Organization (UNESCO)
3. U.N. Standards Co-ordinating Committee (UNSCC)

Others in which lesser scientific interest has been shown are :—

(a) U.N. Relief & Rehabilitation Administration (UNRRA)
(b) U.N. Information Organization (London and Washington) (UNIO)
(c) International Wheat Council

1. SCIENTIFIC CO-OPERATION WITH UNFAO

In the field of food production from agricultural sources, New Zealand is able to make important contributions to the world pool. Any increase in our capacity for food production must be based on existing scientific knowledge, or the concentration of research on our major problems in the agricultural field, and the rapid application of the findings. It has already been estimated that we could increase our output of dairy products by 25–30 per cent by the application of existing knowledge. This presents a very important challenge to New Zealand as an Empire unit. The manner in which Empire co-operation can be achieved most effectively in assisting food production in the agricultural field would be (i) secondment of expert personnel to work in teams on specific problems in New Zealand, (ii) indication from the Official Conference to New Zealand of the order of reference and priority of specific research work in relation to the general problem, (iii) Empire co-operation on the financial side,—investigations proving too costly to a small country but likely to yield returns on the food production front should be assisted.

Problems then which are of Empire interest in New Zealand on the food front are first—application of existing knowledge to a more intense degree ; second—some order of priority for research projects aimed at increasing our production.

Problems coming in the second category are as follows : (a) soil survey and land utilization studies, (b) grassland research and pasture management, (c) soil conservation, particularly in the higher altitude areas,

(d) improvement of production through breeding and selection, herd testing, top-dressing etc., (e) research on milk by-products, particularly dried milk production, (f) animal and plant diseases, and (g) nutrition of livestock, including the use of supplementary fodders. Further to these main problems are those of a possible lower priority, including research on wheat and other grain crops, fruit of all types, vegetable crops and fisheries resources including by-products.

Shortage of trained professional officers will definitely retard the progress of a number of these projects. The Empire may be able to assist by drawing scientific men away from non-food producing interests, or arranging a redistribution of technical personnel to enable New Zealand to supply more food. Other projects will require large sums of money, but again arranged in the right priority.

If Empire co-operation in the scientific field is to be a practical thing, then assistance to UNFAO along these lines must receive consideration.

2. SCIENTIFIC CO-OPERATION WITH UNESCO

The final details of the organization UNESCO have not yet reached New Zealand. Co-operation in the scientific field will be effected with two of the committees: *Committee* A—humanities and science, and *Committee* D—libraries, museums, exchanges, publications, special projects.

Committee A

Empire co-operation in the field of natural and pure science can be achieved in a number of ways outlined in various papers presented to this Conference: (i) the widespread free interchange of information by the methods outlined in the paper on morning subject (**e**) in this series from New Zealand, can be one outstanding method of co-operation, (ii) the exchange of scientists both temporary and permanent can be a very real way to bring about a better understanding and a lasting benefit to Empire outposts, (iii) teamwork of Empire scientists on problems of mutual interest, as during the war years, should be carried forward and intensified in the peace. This is already envisaged in certain fields of research and could well be applied to other projects selected by the Conference.

Committee D

Libraries—Empire linking of library and information services as postulated in the paper on morning subject (**e**) in this series, would be a valuable step forward. Free interloan photostat or microfilm services should be arranged on a co-operative basis. Respective governments should be prepared to bear the small cost involved in this compared with the ultimate gain.

Museums—Here again free exchange of material can be sponsored by this Committee. Museums can do much to assist in building up a knowledge of Empire resources by organized exchanges.

Publications—This matter has also been dealt with in the paper referred to above. The Committee of UNESCO could do much in organizing the first steps towards revolutionizing the present arrangement in connexion with scientific publications and abstracting services. The achievement of international co-operation in this sphere, sponsored by the Empire would be well worth while.

3. SCIENTIFIC CO-OPERATION WITH UNSCC

The New Zealand Standards Institute has been linked with Empire Standards Institutions since its inception. It is represented on UNSCC and draft specifications of proposed international standards are submitted to New Zealand for comment. Free interchange of both published and projected standards has previously taken place between Empire countries, particularly with Great Britain.

The major tasks at present before this Committee include a number in which New Zealand has a vital interest. These are : moisture regain in wool, international co-ordination of building standards, sheet and wire gauges, radio interference, machine tools. Many more will be submitted in the years ahead.

The machinery at present operating for the submission of these international standards to each country through the co-ordinating Committee meets with the full approval of New Zealand.

4. OTHER UNITED NATIONS ORGANIZATIONS

New Zealand assistance in the scientific field to UNRRA has chiefly been through the provision of a small number of expert technical personnel for specialist work in Europe and China. Some provision of technical books, agricultural seeds and medical supplies has also been made.

The International Wheat Council, and the United Nations Information Organizations in London and Washington, carry our support but do not impinge to any great degree on the scientific field which is the subject of this paper.

Although New Zealand is a small unit of the United Nations Organization, she is prepared to play her part in the scientific field to the full. Her contribution to peace will be no less than her contribution to winning the war.

EMPIRE CO-OPERATION IN THE SCIENTIFIC FIELD WITH UNESCO AND OTHER UNITED NATIONS ORGANIZATIONS

By Dr Julian Huxley, F.R.S.
(Executive Secretary, UNESCO Preparatory Commission)

Note—This paper was written by Dr Huxley in 1946 when UNESCO was still in a preparatory stage. Since then the constitution of the organization has been ratified by thirty governments and UNESCO is now in official existence with Dr Huxley as its first Director-General. No attempt has been made to bring the paper up to date. Further information can be found in the published records and appendices of the UNESCO General Conference 1946.

1. In this paper I propose to deal primarily with the relations of Empire scientific co-operation to UNESCO, as this is the only UN organization of which I have special knowledge. In most cases, however, relations with other inter-governmental (UN) organizations will clearly be of the same general type.

UNESCO AND ITS FUNCTIONS IN THE FIELD OF SCIENCE

First of all I want to enter a caveat. UNESCO itself does not yet exist, but only the Preparatory Commission of UNESCO. The ideas and conclusions which this body reaches will be laid before the first General Conference of UNESCO itself in November in Paris, and will doubtless undergo modification at its hands. Meanwhile we have not yet even had time to work out these ideas in full, so that anything I can say now, so far as UNESCO is concerned, must be regarded as doubly provisional.

2. With this caveat, I will begin by saying something about the aims and methods of working of the scientific section of UNESCO. In the first place, one must contrast the approach to be adopted in this section, together with the other section, namely the social sciences, concerned with the advancement of knowledge and learning, with that to be adopted in those dealing with literature and the arts. In the latter, the quality of the individual work of art is what counts, and local variety must be encouraged. In the former, quantitative amount and high standard of performance is of the prime importance, and UNESCO should aim at encouraging a single and unified advance for the world as a whole.

As regards the natural sciences, pure and applied, we first of all have a temporary task, in relation to relief and rehabilitation. This we are undertaking jointly with UNRRA, which does the actual work in the field. While, as I say, this is essentially a temporary activity, it must

clearly link up with any long-term plan of aid to science. In several ways, indeed, it has already done so, for instance in the scheme for standardizing scientific apparatus which has grown out of the discovery of the unnecessary multiplicity of types now existing. In surveying the needs of the world, we must pay special attention to those areas in which science at the moment is less well developed, whether this be because of war devastation or for historical or geographical reasons.

As regards our permanent activities in science, these will fall into three main groups :—

(*a*) organization, facilitation and stimulation,
(*b*) survey and the provision of information,
(*c*) participation in actual projects.

3. As we shall be operating with a limited budget, one obvious principle which we must adopt is that we should undertake nothing which other international organizations are doing or could be persuaded to do. Further, that we shall not seek to impose policies, but work by persuasion and co-operation. With these aims in view, we have already entered into negotiations with the ICSU (International Council of Scientific Unions) with a view to concluding an agreement with them, by which we shall facilitate their work in various ways, notably by providing funds for secretarial and similar services. We shall endeavour to enter into arrangements of similar type with other international organizations, such as the International Bureau of Weights and Measures and the International Anti-Locust Research Centre.

As regards previous efforts at international action in the field of science, two distinct types of organization have come into existence. First those typified by the International Scientific Unions ; secondly, those typified by the science co-operation offices set up during the war by various governments, usually but not always for war purposes exclusively. The former are directly international, but are limited as to subject-matter, each dealing with only one branch of science ; the latter are not limited by subject-matter, but by the region of the world in which they happen to be situated, and by the fact that they are bilateral organizations, from one single nation to another. A modification of this latter type was by the BCSO (British Commonwealth Scientific Office) in Washington, in which a number of delegations from the separate nations of the British Commonwealth participated.

4. As regards actual work, we may classify this under the following headings :—

(*a*) To facilitate, stimulate, and help in servicing other organizations already in the field, which are themselves international or performing an international service ; e.g., we might materially help the International Scientific Unions by collecting their dues for them. Further, to co-operate with the scientific sections of the National Commissions or National Co-operating Bodies which all state members of UNESCO are under obligation to set up to represent the educational, scientific and cultural interests within their boundaries.

(*b*) To co-operate in the scientific field with other organs of the UN, e.g., the three Councils, the Atomic Commission, FAO, ILO, the projected World Health Organization, PICAO (dealing with civil aviation) Commission, the proposed International Trade Organization, etc. Thus, in regard to backward areas, UNESCO will have to co-operate closely both with the Trusteeship Council and with the section of the Economic and Social Council dealing with dependent territories.

(*c*) To survey the existing world set-up of science in order to discover what gaps exist :

(i) among international organizations (e.g., there appears to be nothing corresponding to the International Council of Scientific Unions in the spheres of engineering, medicine and agriculture, and no International Unions at all for certain important sections of engineering).

(ii) in problems being undertaken on a world scale ; e.g., an adequate survey of the world's natural resources ; a survey of the state and type of scientific organization, country by country, throughout the world, including the percentage of the national budget spent on scientific research, and the scientific manpower available and required ; broad surveys dealing with the scientific problems of geographical zones, e.g., the tropical rain-forest zone, the tropical arid zones, the polar zones, etc.

(iii) in the geographical distribution of scientific institutes or activities (e.g., there are no first-class astronomical observatories and few meteorological stations in the Southern hemisphere).

(*d*) To promote the fullest flow of scientific information. This will include the co-ordination and improvement of abstracting services, of reviewing journals, and possibly the rationalization of the whole system of scientific publication.

(*e*) To collect and provide information of special sorts, e.g. :

(i) to stimulate the production of a 'Directory of Science and Learning,' which would list not only the names and positions of all scientists (and other academic and research personnel) throughout the world, but the technical facilities available in their laboratories and the chief problems in which they are interested.

(ii) to arrange for the publication of multilingual dictionaries of scientific and technical terms.

(iii) to produce a regular calendar of international scientific congresses and other gatherings.

(iv) to aid in the publication of certain types of scientific data (e.g., critical tables).

(*f*) To promote the highest degree of standardization—of terminology, of zoological and botanical nomenclature, of measurement, of materials, and of apparatus.

(*g*) To promote the movement of scientific personnel, apparatus, publications, information, films, etc., across national frontiers. This will mean participation with other sections of UNESCO (i) in a move for a convention covering the flow and exchange of scientific films and apparatus ; (ii) in arranging for an accounting system which might in many cases obviate the necessity of nations making payments in foreign exchange. A proposal has also been made for a scientific ' carte d'identité ' to establish the nature of the work and the credentials of scientists desirous of travelling, which may obviate difficulties now that scientific secrecy and censorship is having to be imposed, for security reasons, in an increasing number of fields.

(*h*) In general, to help in raising the quantity and level of scientific work in the less advanced areas of the world towards that in the more advanced.

(*i*) To take over the financial and administrative responsibility for various international scientific projects which are already going concerns, e.g., the Bureau de l'Heure, the various collections of type cultures, etc. : the scientific responsibility would remain in the hands of the appropriate International Scientific Union.

(*j*) To co-operate with our educational section in arranging for the best employment of scientific method in education (including adult education in the broadest sense) and for the improvement of its scientific content, e.g., by making known the best methods in the domain of intelligence and other testing ; in working out a syllabus for a course in general science as part of a general cultural education ; in stimulating the fuller and better use of scientific material and ideas in the press and on the radio ; in preparing an annotated list of scientific films and in arranging for subtitles in other languages, etc.

(*k*) To undertake or promote actual new projects. Owing to budgetary limitations, UNESCO is adopting the general principle that it will have to confine itself to a series of sample or pilot projects, illustrating what can be done in certain fields. The financing and accounting for many of these would have to be separate from the ordinary UNESCO budget. Among such sample projects we may mention—

(i) a UNESCO centre for applied mathematics, to be equipped with the latest type of calculating machines, e.g. in a country like India.

(ii) a station or institute for the scientific study of the problems of the tropical rain-forest zone.

(iii) a UNESCO observatory in the southern hemisphere.

(iv) a UNESCO meteorological station or institute in the southern hemisphere.

The Preparatory Commission of UNESCO has approved the first of these as a priority project, and has recommended preliminary study and co-ordination work on the second.

5. In addition, each year it is hoped to stage 'UNESCO Month' celebrations in the capital of the country in which the annual conference is held, and at the same time to ask that all member nations shall stage a 'UNESCO Day' in their own countries. In all such celebrations science would, of course, play a part.

It is clear that in order to cover this programme adequately, the natural sciences section of UNESCO will have to co-operate with other sections, e.g., with that for social sciences, for education, for libraries and museums, for mass media, for philosophy, and indeed with the arts section, notably in the field of architecture and building.

6. The question of co-operation with other governmental and inter-governmental agencies engaged on similar tasks is clearly a difficult and urgent problem. The case of other UN organizations, such as the FAO, the new Health Organization, the Atomic Commission, the UN Information Service, etc., is comparatively straightforward. Here agreements will be entered into defining the fields of competence of UNESCO and the other agencies concerned, and laying down the lines along which co-operation shall proceed.

In the national field a whole network of activities concerned with science in other countries is springing up. Scientific missions are frequently sent to particular nations or regions ; there are proposals for a large increase in the number of scientific attachés ; there are agencies aimed at projecting the culture, including science, of nations to the rest of the world, such as the British Council and other organizations. In addition, of course, there are agencies responsible for the development and organization of science within nations, e.g., in Britain the three Government Research Councils and the Cabinet Scientific Office.

Then there are efforts made by confederated groups of nations. The most obvious example is the British Commonwealth, for which the present conference is now considering the best methods of scientific organization.

It is clear that these different types of effort need linking up and co-ordination if there is not to be much overlap and waste of effort and, perhaps most important of all, if the rather scarce manpower suitable for such work is to be economized—a point which Dr King has rightly stressed in his paper.*

TYPES OF CO-ORDINATION BETWEEN UNESCO AND OTHER AGENCIES, NOTABLY ANY BRITISH COMMONWEALTH SCIENCE SERVICE (BCSS)

7. At UNESCO headquarters (Paris)

Here UNESCO policy in science will be determined and much information centralized. Co-operation with BCSS will be mutually beneficial in such matters as the following :

(a) in schemes for improvement of abstracting and reviewing scientific publication in general.

* *International Relations in Science,* Royal Society Empire Scientific Conference, 1946. ii, 116.

(*b*) in the compilation of the scientific section of a world 'Directory of Science and Learning.'

(*c*) in sub-titling scientific films for use in different areas of the world and in compiling improved catalogues of good scientific films and in obtaining exemption of duty for them.

(*d*) in framing policy for the better dissemination of results of scientific research at all levels in less advanced areas, especially those with a high illiteracy rate.

(*e*) in framing policy for survey or research on local or zonal problems.

(*f*) in making a world survey of natural resources, if this is decided upon.

(*g*) in schemes for improving scientific standardization.

8. However, the *regional centres* will be in my opinion the places where the most fruitful co-operation can take place for dealing with Commonwealth scientific problems, and I shall set forth the possibilities provided by the regions for establishing a bridge between national and international organizations dealing with science (as well as with other subjects).

Let us illustrate by a number of concrete examples—

9. SPECIALIST ATTACHÉS

Let us assume that Great Britain intended as part of its general diplomatic programme to appoint scientific attachés to its embassies abroad ; then in the case of a region like South America, even if it decided to appoint such attachés only to the major among the ten nations involved, this would mean five or six scientific attachés for the region. These would in all probability be youngish men, who would have to live in scientific isolation and act as scientific Jacks-of-all-trades. If, on the contrary, a UN regional centre were in existence, two or at most three 'attachés-at-large' could be appointed to the region, who would spend about half their time in the field, in various of the countries comprising the region, the rest at the regional centre.

This in itself would provide for some degree of specialization. Further, if a number of nations were appointing scientific attachés of this type, the director of the regional centre could write to the various governments, suggesting that their own national interests (as well as those of the region as a whole) would best be served if specialists were selected, in such a way that the scientific attachés as a group, together with any UN scientific staff at the centre, constituted a well-balanced team covering the main fields of science. As Dr King has described in detail in his paper, an arrangement of this sort was gradually worked out on the spot by the BCSO in Washington during the war, so that a considerable amount of division of scientific labour took place among the twenty-five members of its five national delegations. This resulted in a considerable increase of all-round efficiency, an increase which would have been greater if proper selection could have been made at the outset. Even if such a method were agreed to in only half the cases at the regional centre, it would result in a corresponding increase of scientific efficiency.

Furthermore, at the BCSO the separate governmental delegations agreed to devote some of their time to working as a single team, in which effort should be pooled and in common, while of course reserving their right and duty to act in a purely national capacity when desirable. In point of fact, it was found that joint working so much increased their efficiency, even from the purely national point of view, that the method came to be adopted for the great majority of their time. The same request could be made of the scientific attachés in a region, and would undoubtedly be found to produce a corresponding increase of efficiency.

10. Special missions, visitors, exchange professors, etc.

When a regional centre is in operation, all scientific and technical missions, distinguished academic and specialist visitors in science and technology, and exchange professors, who are proceeding to separate countries in the region should be invited to spend some time at the regional centre. This would presumably be in a 'UNESCO house' specially erected for such visitors. The success of the Society for Visiting Scientists in London shows what results might be anticipated from the extension of such schemes on to the international plane, and into all branches of science and culture. Though many might be unable to spare the time, the visits of those who could do so would considerably enhance the intellectual life and activity of the centre.

11. Scientific representation of the nations within the region

In many cases, representatives of the science sections of the National Commissions to be set up in every member country for liaison with UNESCO, and/or representatives of government scientific organizations, would be attached to each regional centre. This would in particular promote the growth of a common attitude among the nations of the region towards problems of scientific research and its applications, as well as facilitating the scientific work of the centre, and interlocking with that of the agencies next to be mentioned.

12. Agencies for projecting national cultures abroad

These, such as the Bureau de Relations Culturelles in France, the British Council, and the Cultural Relations Division of the U.S. State Department, will also profit by having representatives at regional centres for some or all of the time.

To take one example, separate British or French Exhibitions of science may often be regarded with a certain suspicion, as national propaganda, while precisely the same material, if part of an international exhibition, would arouse no such suspicion and would be correspondingly more effective. The organization of such international or multi-national exhibitions within a region can clearly best be arranged and facilitated at the regional centre, with the aid of the UN staff, the national representatives within the region, and the cultural agencies or specialist attachés of nations outside the region.

Again, by co-operating with each other through their representatives at the regional centre, cultural agencies might well come to appreciate the advantage of co-operating in concrete projects in the same or other cities.

13. REGIONAL SELECTION BOARDS

Where possible, but especially when more than one nation within a region is providing fellowships tenable in other regions, it would be desirable to set up regional selection boards, preferably under the chairmanship of a UNESCO official, and composed of representatives from various countries within the region (perhaps together with scientific attachés from the 'receiving' countries). This would facilitate the co-ordination of such national fellowship schemes within a coherent world system, and add a certain international character to the fellowships, as well as helping to establish high standards of selection and the practice of international collaboration within the region.

14. It is clear that the presence of a regional office of the BCSS would be extremely valuable, both to BCSS itself and to UNESCO and other UN agencies and organizations, in those regions in which Dominions or dependencies of the British Commonwealth are strongly represented—i.e., Africa, Australasia, the Indian region, the Caribbean region, and to a slightly less extent the Middle and Far Eastern regions. These BCSS centres could play a part essentially similar to that played by the BCSO in Washington.

Conditions are rather different as regards the North American region. For one thing, the headquarters of most UN organizations and agencies are located here, so that there would be no need for a UN regional centre but merely for the presence of a liaison office from UNESCO and other agencies with headquarters outside this region. Secondly, it seems fairly clear that the natural site for a BCSS office in this region would continue to be Washington rather than New York or its vicinity, though it should presumably have liaison offices and/or facilities in New York and Ottawa.

Further, if, as I assume, the BCSS is anxious (*a*) to gather scientific information from, and (*b*) to serve as an outgoing channel of scientific information to all foreign countries, and to project British scientific culture abroad, it will be useful and indeed necessary for it to have at least one 'scientific attaché,' and probably a small group of scientific officers, in Eastern Europe and South America as well. For Western Europe, London will presumably serve as the headquarters of the BCSS, from which it will be quite simple to maintain liaison with UNESCO headquarters in Paris.

One task in which co-operation between UNESCO and the BCSS at the regional level will clearly be of great importance is in the dissemination of scientific information, both of the results of research to specialists and of its applications to technicians, and the wide dissemination of scientific knowledge to the general public.

15. It is not contemplated that UNESCO or UN regional centres should be set up except in one city in each of the approximately ten major cultural regions of the world, and for the time being it is probably best that effort should be concentrated on creating not more than three sample centres, perhaps in the Middle and the Far East and in South America.* However, it will presumably be desirable for BCSS to practise a further degree of

* A further degree of decentralization will probably be needed by the UN information service, and UNESCO and other specialized agencies will doubtless require correspondents in all or many nations.

decentralization in certain areas (e.g. within the African region, in the natural sub-regions of West Africa, East and East Central Africa, and South and South Central Africa). Again, in the Far Eastern region, Malaya and the East Indies constitute either one or probably two natural sub-regions. In all such sub-regions the main task of BCSS would presumably be to secure co-operation on scientific problems affecting the area as a whole, between the British dependencies, those of other colonial powers, and any self-governing countries in the area. If the BCSS were to set up offices in areas of this type they could clearly be of great service to UNESCO, and it would almost certainly be desirable for the scientific section of UNESCO to have whole- or part-time representatives at them.

16. I anticipate that UNESCO, in surveying the gaps in world scientific organization and the unequal distribution of world scientific effort, will find it desirable to urge, or actually to undertake, certain special types of projects in which geographical location is important ; e.g., in the southern hemisphere, as already indicated, there is a serious shortage of good astronomical observatories and of modern meteorological stations. Again, although a great many problems of research and its application are essentially zonal, no agencies now exist for undertaking a survey of the scientific problems of a geographical zone as a whole. As examples of such problems we may take that of human life in the polar zones, which depends largely on providing adequate heating and adequate variety of food ; that of human life in the equatorial forest zone, which depends largely on combating disease and on providing cooling facilities ; and that of human life in the arid tropical zones, which depends largely on increasing the available water-supply and on preventing erosion. In any projects of research or survey of this type, it is clear that BCSS would be deeply interested, and would be able to give considerable help to UNESCO.

17. In other cases, the British Commonwealth has already set up research or survey organizations which, if co-operation could be arranged (presumably through UNESCO), might be enlarged or extended to serve as international agencies on a world or a zonal scale—e.g., the Imperial College of Tropical Agriculture in Trinidad, the East African Research Institute at Amani, the Imperial Bureaux.

Again, the scientific section of UNESCO considers one of its major duties to be the raising of the amount and level of scientific personnel and facilities in the less favoured regions of the world towards that prevailing in the more advanced regions. Here again it is clear that BCSS will be interested, and that both parties would profit from co-operation.

Among other types of projects, it has been suggested that the UNESCO Centre for Applied Mathematics (para. 4 (*k*)) should be situated in a region in which mathematics were sufficiently far advanced for the enterprise to be adequately carried on, but where it is unlikely that a centre of this sort would be set up without initiative from outside. India would be one of the obvious areas for such an enterprise ; if this were decided upon, it would clearly also interest BCSS. Similarly, BCSS could co-operate to mutual advantage in any survey of the natural resources of the world, which UNESCO might be asked to undertake.

18. In regard to collaboration between BCSS and other specialized agencies of the UN, notably the FAO and the Health Organization, it

would seem that a similar pattern of co-operation to that proposed with UNESCO would be the most suitable. There would also, however, be need for liaison between BCSS (with special reference to the Colonial Research Committees and Councils) and (*a*) the Trusteeship Council, and (*b*) the section of the Economic and Social Council dealing with dependent territories, over what we may call the 'Colonial' problems of science and its application. Co-operation with the Security Council will be on a rather different footing. Possibly, any liaison here should be through the Atomic Energy Commission, and the Atomic Development Agency if set up; direct liaison and delimitation of functions with these will in any case, of course, be necessary.

19. In general, we must constantly recall that science is one, and advances best and most rapidly as a single world movement which is at a high level everywhere instead of at a high level in some areas and at a low level in others. If we agree to this, it is clear that the maximum amount of fruitful co-operation must be arranged between the scientific section of UNESCO and any scientific organization set up for the Commonwealth as a whole, both as regards exchange, scientific facilities such as abstracting, co-operation on any concrete projects, and pooling of resources of scientific manpower, wherever possible.

INTERNATIONAL RELATIONS IN SCIENCE

By Dr Alexander King
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Appendices

THE INTERNATIONAL NATURE OF SCIENTIFIC ACTIVITY

Of all the fields of human experience and endeavour, science has remained the most genuinely international in both content and development. None of the sciences has developed exclusively in a single country or in a particular region of the world, but rather through contributions from individuals in many lands equipped with a common background of experience and possessing research tools of the same general nature. Up to the present there has been little or no attempt to keep secret within the

confines of a single country or within a private group, discoveries of a fundamental nature. Except during the interruptions of war scientists of all nations have been in continuous and intimate contact respecting their work.

In technology the situation is quite otherwise. As long as nationalism persists achievements and information gained, for example in the application of science to warfare, must, as far as possible, remain the property of the originating country. When these discoveries are ultimately disclosed it is generally found that development has taken place along broadly similar lines in all those countries where scientific achievement and technical resources were of the same order. This is, of course, due to the fact that such developments of technical warfare are based on identical scientific principles already well known internationally before the war, and is a potent argument for the sharing of armament secrets by friendly nations intending to keep in the vanguard of military development.

In commerce, practical techniques of manufacture and use can remain the monopoly of a firm or individual only during the life of a patent; thereafter they revert to the common pool of technical knowledge, more or less freely available to all those capable of using it.

The reason why firms and governments have, until now, seldom tried to extend this proprietary attitude from inventions of industrial or military technology to the discoveries of pure science has been mainly ignorance on the part of industrialists and politicians as to the implications of academic research. The growing recognition of the practical importance of academic research as well as the shortened period required for its technical development are now beginning to threaten that freedom of science which is necessary for its healthy cultivation. Naturally enough scientists throughout the world are expressing alarm at a tendency which may, in the interest of national survival, threaten to restrict scientific collaboration between research workers of different nations.

On the other hand, the recognition of the importance of basic scientific research stimulates fundamental research by organizations dependent on the results of applied research but sufficiently enlightened to be willing to forego immediate financial return on money expended on science, with the result that first-class workers have been enabled to prosecute their research with as much freedom as in an academic laboratory.

INTERNATIONAL COLLABORATION BEFORE THE WAR

Previous to the outbreak of hostilities, academic scientists engaged freely in relations with their specialist colleagues in other countries, criticizing constructively, discussing common problems by correspondence or at international congresses and, particularly in the biological sciences, collaborating actively in the field. Many professors from foreign countries lectured in British universities while our specialists gave accounts of their work abroad. At the student level opportunities for foreign study were provided by many universities and organizations such as those offering the Commonwealth Fellowships, Rhodes Scholarships, 1851 Exhibitions, etc. These and other types of informal international contact had exceedingly important consequences of cross-fertilization in maintaining the health and vigour of research schools throughout the world.

International collaboration, however, went far beyond these spontaneous if somewhat fortuitous contacts between individual workers. In connexion with the re-establishment of international scientific co-operation, the United States Academy of Sciences has compiled a list of international scientific congresses held up to the outbreak of World War II, which shows that in the few years prior to the war almost one thousand international meetings of some four hundred and fifty organizations were held. An analysis of this list is given in appendix (i).

For certain sciences there also existed international unions able to deal with day to day questions of co-operation and to arrange international meetings on particular problems when the need arose.

The National Academies of Science in the different countries have also played an important part in supporting international unions and convening scientific conferences of a truly international character. For instance the Pilgrim Trust Fund administered by the Royal Society and the Academy of Sciences in Washington enables British scientists to give periodical lectures in the United States and American scientists in the United Kingdom.

In the applied sciences including medicine, nutrition, roads and building, meteorology and geophysics, collaboration has been considerable though not as extensive as in the academic sciences. In agriculture, which is the application of all science to the growing of food and organic raw materials, international collaboration has been made possible through the dissemination of information by the Imperial Agricultural Bureaux, which are international in influence though restricted in organization to the countries of the British Commonwealth.

Exchange of information on industrial techniques between the nations took place before the war on a very extensive scale in the form of communication between associated commercial enterprises in several countries, and although this type of international relationship is frowned on in some quarters because of its restrictive aspects on international trade and technical enterprise, the direct passage of information from firm to firm across international boundaries will undoubtedly remain in some form as one of the most important methods of international technical interchange.

In military technology little information was made available before the war even among Allied Governments and most of the reports originating from Service establishments were rigidly restricted in circulation even in the country of origin.

SCIENTIFIC LIAISON DURING THE WAR

It was obvious from the outset that the Second World War was to be a technical war which would strain the scientific resources of the Allies to the utmost. Complete collaboration between the countries of the Commonwealth in science, as in other activities, became an important matter of policy, and the Dominions consequently set up scientific liaison offices in London for the exchange of technical information required by the Service and Supply Departments. New Zealand was the pioneer in Imperial scientific liaison, having supported a scientific representative in London for the last eighteen years.

These Dominion scientific liaison offices in London were most successful

in bringing about scientific collaboration not only between the United Kingdom and the Dominions but between the Dominions themselves. They also formed a centre for visiting scientific specialists from the Dominions.

In 1942 the Royal Society expressed its appreciation of their services by establishing the British Commonwealth Science Committee with the President of the Royal Society as Chairman and the other officers of the Royal Society and the Senior Scientific Liaison Officers as members. This Committee met frequently during 1942 to discuss how the collaboration generated under the exigencies of war might be maintained and adapted to a peace-time world. The report of this Committee, issued in 1943, was communicated to the High Commissioner of each Dominion in London and received general support.

One of the recommendations of the Committee was that 'the Governments of the various English-speaking countries should consider the possibility of maintaining permanent scientific representation in London and possibly in other capital cities of the English-speaking world.'

Further recommendations concerned the desirability of re-forming and rationalizing the present system of scientific abstracts on an international basis and also the means of encouraging the exchange of professors and research workers between countries of the British group. It was from these recommendations that the conception of the present Conference sprang.

In addition eminent scientists visited Canada, Australia, India and the United States. As a result of Professor A. V. Hill's visit to India in 1944 a group of Indian scientists visited England and the United States, inspecting laboratories, experimental establishments and industrial firms. Sir Henry Tizard's mission to the United States in 1940 had led to close co-operation between United States, United Kingdom and Canadian interests and the ultimate establishment in London of a branch of the Office of Scientific Research and Development, the work of which was complementary to that of the U.S. Assistant Naval and Military Attachés delegated for specific technical subjects of Service importance. Although this office has ceased to exist, there are reasons to believe that there will be a continuance of representation in London in some form.*

Corresponding to the London O.S.R.D.,† a British Central Scientific Office was set up in Washington for North America, and rapidly became an active centre for visiting scientists and technicians, and for the exchange of information. As the war developed it was necessary to attach other British scientists and technicians to the various Service and Supply missions in Washington.

Australian, New Zealand and later South African missions were sent to Washington where, together with the United Kingdom and Canadian representatives, they formed a British Commonwealth Scientific Office in 1944. An Indian Scientific Mission has since joined the office.

One important experiment in international science is the Sino-British Scientific Co-operation Office in Chunking, which provides considerable experience on the operation of international scientific exchange on civil science matters. Originally sponsored by the British Council to operate on broad scientific cultural lines it formed a much needed channel during

* See Page 10. † Office of Scientific Research and Development (U.S.A.).

the war for the distribution, through the Ministry of Production, of British technical information to the Chinese.

The passage of technical information between Great Britain and Russia was restricted in the main to purely Service channels. An Anglo-Soviet Technical Committee was, however, set up in London, including in its membership an official of the Russian Embassy. Later in the war an Australian professor was posted to the Australian Legation in Moscow with the rank of Counsellor.

From the above it will be realized that during the war the means for the exchange of scientific and technical information between the Governments of the United Nations were provided to an extent previously unknown in international scientific relations. Co-operation went far beyond this, however, in that research projects of high priority were delegated to the scientists of one or other country to work out on behalf of all, while on many important projects British scientists worked in American laboratories and Americans in British scientific establishments.

THE BRITISH COMMONWEALTH SCIENTIFIC OFFICE IN WASHINGTON—ITS DEVELOPMENT AND MODE OF OPERATION

DEVELOPMENT

The British Central Scientific Office was established in Washington in 1941 to continue the work of Sir Henry Tizard's Technical Mission which arranged for the interchange of scientific and technical information between the United States and Great Britain. The Central Scientific Office worked in close contact with the Office of Scientific Research and Development of the U.S.A. and contacts and exchanges were also maintained with the U.S. Services and other Government Departments.

In the beginning B.C.S.O. was a purely civilian organization like O.S.R.D., but with the entry of America into the war and the beginning of lend-lease operations there was a tendency for B.C.S.O. to be interested in war projects of an essentially inter-departmental or inter-Service character.

In 1941 Australia and New Zealand established Scientific Liaison Officers in Washington. These were attached to the Australian Legation and the New Zealand Supply Mission respectively, and while working as far as possible through B.C.S.O. also dealt directly with the United States authorities.

In 1943, in order to effect closer co-operation, the Liaison Offices of Australia and New Zealand moved into accommodation adjacent to B.C.S.O. and in 1944 the three offices, by mutual agreement, associated with the new Mission from South Africa and with the Scientific Liaison Office of the National Research Council of Canada to form the British Commonwealth Scientific Office, the original B.C.S.O. being renamed the United Kingdom Scientific Mission.

Until the end of the war the U.K.S.M., which is an inter-departmental group, was governed by a Scientific Sub-Committee of the North America Supply Committee of the War Cabinet in London ; its officers were on

the establishment of the Ministry of Production. On 1 February 1946, the U.K.S.M. was transferred to the vote of the Department of Scientific and Industrial Research, but its general arrangements are still discussed by an inter-departmental Civil Science Panel of the organization which, under the Lord President, deals with scientific relations with other countries.

Recently too, the U.K. Mission has been able to undertake work on behalf of the Colonies, in particular the British West Indian Colonies, Palestine and Southern Rhodesia, which are in contact with B.C.S.O., Washington, and receive routine reports from them.

An Indian Scientific Mission has also recently joined the Office.

MODE OF OPERATION

At the outset the most obvious type of collaboration was on routine matters common to the constituent missions and accordingly a Common Services Section of the Office, previously part of the U.K. Mission, was made available to the Dominions. This section was responsible for a visits bureau, a central index, a comprehensive library of technical reports and a duplicating section. It also undertook the distribution of documents, the provision of auxiliary stenographic assistance and the purchasing of books and apparatus. Details of its activities are given in appendix (ii).

In addition to the economy and efficiency resulting from these common services the Commonwealth Office has increased the scope of work of each of its units by the principle of common representation on scientific matters. In this way each unit is able to cover a field vastly wider than was possible previously.

One of the main functions of B.C.S.O. is to transmit detailed information on technical research and development between the United States and the British Commonwealth. Experience shows that it requires a specialist with a background of knowledge and experience to obtain the requisite information. This would be impossible without the combined action introduced by the federation of individual missions. The seventeen scientists of B.C.S.O. naturally cannot provide specialized liaison over the whole field of science but with the assistance of the relatively large numbers of specialist visitors they have become semi-specialists on most of it. In return the specialists, who have numbered as many as twenty-five at one time, benefit by the general information possessed by the B.C.S.O. scientists.

The main functions of B.C.S.O. as a scientific liaison office can be summarized thus :

(*a*) To act as a centre for official scientific visitors from the home countries, and to help them with contacts and introductions and to provide travel and hotel facilities, clearances, etc.

(*b*) To maintain cordial relations with the various scientific and technical bureaux of the United States Government as well as research associations, universities and other institutions.

(*c*) By means of requests made by the scientific officers to their American colleagues, to obtain prompt and comprehensive answers to questions asked by Government departments in the home countries.

(*d*) To stimulate and maintain the flow of scientific and technical reports from United States laboratories to Government departments in the home countries and to see that corresponding British reports reach the proper recipients in the United States.

(*e*) To report new developments and changes in policy and organization on scientific matters in the United States.

(*f*) To purchase books, journals, specifications, chemicals, scientific apparatus and biological materials for official scientists of the various countries supporting the office.

(*g*) To act as advisers to agencies of the Commonwealth countries in the United States on service, industrial and other aspects of science.

(*h*) To arrange for British-American collaboration on research projects whenever this may appear appropriate.

It must be stressed that the existence of an office of this type is in no way an obstacle to personal contacts between scientists in the British countries and their colleagues in the United States. Indeed it has an important function in initiating such. Nevertheless it is useful in the interests of continuity that major Government scientific transactions be channelled through such an office in order that it may give help when required.

THE ADVANTAGES OF THE COMMONWEALTH SYSTEM

The success of the federal type of organization operating in B.C.S.O., Washington, is such as to warrant consideration as a possible pattern for post-war collaboration with other nations.

The chief advantages of the system may be stated as follows :

(*a*) An expert and efficient scientific information service is provided by the association of a few scientists from each of several participating countries. It is a compromise between the two extremes of a ' post-office ' and a large and expensive assembly of experts, which is only made possible by combined working.

(*b*) The B.C.S.O. system provides, by close proximity of scientists from the different British countries, a truly scientific atmosphere and encourages a broader understanding of the problems involved. The day to day discussions lead to a greater understanding of one another's problems and a broader appreciation of the necessity for common scientific approach.

(*c*) Economy of time and labour is achieved by the possibility of a joint approach to the United States authorities in many questions of common interest to several or all of the members of the Commonwealth.

THE NECESSITY FOR CONTINUING INTERNATIONAL COLLABORATION IN SCIENCE AND TECHNOLOGY

To practically all scientists it is a matter of axiomatic belief that fundamental scientific research can only flourish if free from restrictions of security and bureaucratic control. Any formal arrangements made by governments for the encouragement of scientific relations between them

should therefore be sufficiently flexible to give the maximum help to independent scientists without restricting them.

While those engaged on fundamental research will expect their governments to create, by means of their domestic and foreign policies, circumstances favourable to free communication of ideas rather than to erect machinery for formal exchange of information, the situation may be quite otherwise in the applied sciences.

Even before the war the need was recognized for government research into certain subjects of national importance such as :

Defence.
Agriculture, animal husbandry, soil conservation, etc.
Public health ; water and atmospheric pollution.
Meteorology and weather prediction.
Geological and geodetic surveys.
Safety in mines and in industry.
National standards of all kinds.
Food and nutrition.
Radio communication.
Transport.
Building.

In addition huge development programmes have been undertaken, e.g. in America, in those industries where development costs are too high for commercial firms and where national initiative is necessary for efficient exploitation of important raw materials.

The scale and success of war-time research in the Allied countries has been made possible on the one hand by the allocation of national funds and the concentration of scientific man-power, and on the other, by central and uncompetitive planning of governments driven to an appreciation of science by the overwhelming urgency of the situation. Scientists and laymen alike have been impressed by the great potentialities of science for human welfare when organized on this scale and the view is widely held that national governments must intervene if the possibilities of science are to be used to the full for human advancement.

The amount of scientific research and technical development which will take place in the future in the countries of the British Commonwealth, the United States and Russia will undoubtedly be very much greater than before, and a much larger proportion of it will be either directed or encouraged by Government. The question of scientific interchange between governments is therefore a matter of first importance in any scheme of international co-operation. The political advantages which would accrue from closer scientific collaboration between the nations of the world and the international understanding which would result from the relations of their scientists would alone be ample return for the cost in money and man-power of such schemes.

VARIOUS SUGGESTED MEANS OF EFFECTING INTERNATIONAL SCIENTIFIC LIAISON

It is in relation to the social aspects of science that the need for international scientific relations has been chiefly stressed, both in connexion

with the prevention of war and the alleviation of its consequences. Significantly enough, the call for the establishment of such relations has come from the people as well as the scientists.

Many suggestions have already been put forward as to how such scientific relations might be operated, and although consideration of the official policy and the machinery required to secure the proposed results is a matter for the Official Conference, it may be useful at this stage to indicate some of the existing machinery and possible lines of development.

The different proposals for international science are roughly divided into two categories, national and international.

National, i.e. those which envisage relations being maintained between scientific groups from different countries. Among these are :

(*a*) *Relations between the various National Academies of Science*

The Division of Foreign Relations of the National Research Council of the United States has undertaken a survey of the present status of international scientific machinery and has put forward the following recommendations :

(i) That the Foreign Secretaries of the Russian Academy of Science, The Royal Society of Great Britain and the National Academy of Sciences of the United States should explore the possibility of an inter-academy study of their international relations in these phases of science which are of benefit to all men and inimical to none.

(ii) That the International Council of Scientific Unions, through its British and American offices should simultaneously prepare a memorandum for all governments which have adhered to the International Scientific Unions, on how the Unions may best collaborate in post-war research and educational problems.

(iii) That the Division of Foreign Relations of the National Research Council should continue to advise the U.S. Academy of Sciences in all international scientific matters which may or may not be in the self-interest of the United States.

(*b*) *Official scientific and technical relations*

The establishment by the United Kingdom Government of a series of inter-departmental committees to consider various aspects of scientific collaboration with other governments (in particular the question of British scientific representation abroad), and the statements and action to the same effect which have emanated from Dominion Governments, are ample evidence of the serious interest of His Majesty's Governments throughout the Commonwealth in these problems.

In the United States, the reports submitted to the President by Dr Vannevar Bush under the title '*Science—The Endless Frontier*' and the wide provision for technical collaboration with other nations contained in recent drafts of the various Science Bills now before Congress point to a similar attitude. A further if somewhat unilateral action is that of the U.S. Navy Department which has set up in London a European Branch of its office of Research and Invention to maintain contact in various fields of fundamental scientific research in Great Britain.

(*c*) *Proposals for Scientific Attachés*

The suggestion has been put forward from many quarters, both British and foreign, that the Governments of the major United Nations should appoint scientific attachés in their Embassies and Legations, to provide scientific co-operation and arrange for the exchange of technical information. The main task envisaged is that of assessing the political and economic importance of scientific trends in industry and raw materials, but in addition the Scientific Attaché might effect liaison between the scientific and technical associations of the two countries.

The results of the Parliamentary and Scientific Committee's inquiry on the subject show that the general opinion of senior British scientists is favourable, but difficulty is foreseen in providing suitable men.

International, i.e. those which assume that the international agencies attached to the United Nations Organization should be the chief vehicles for scientific transactions between the nations.

(*a*) *International Scientific Co-operation Service* (*I.S.C.S.*)

Dr Joseph Needham from his experience in the British Scientific Office, China, advocates the establishment of the above Service to promote all kinds of scientific co-operation. Furthermore its staff could provide scientific advice to government and diplomatic personnel if required and assist other international organizations. It would, presumably, be operated by U.N.E.S.C.O. and would cover interchange in applied as well as pure science.

(*b*) *Science in the United Nations Organization*

Considerable discussion has already taken place in the operational agencies of U.N.O., for instance in the Food and Agricultural Organization, U.N.E.S.C.O., and the Atomic Energy Commission, all of which may be expected to promote the general interchange of information and co-operation between the nations.

Further details of these points are given on page 130.

It should be possible to combine the essentials of all these schemes in a single one incorporating the advantages of all and at the same time retaining the results of experience gained in the war-time Scientific Liaison Offices of the members of the United Nations. Any scheme adopted for the Commonwealth should be considered with regard to its possible extension on an international scale.

THE RANGE OF ACTIVITY OF INTERNATIONAL SCIENTIFIC LIAISON

Before putting forward a scheme for Commonwealth and International co-operation in Science, it is appropriate to examine the different classes of research and development activity in which there is a national interest and in which the liaison officer has a possible role. These activities may be classified as

(*a*) academic research
(*b*) research and development matters relating to defence

(*c*) government-sponsored civilian research
(*d*) collective research
(*e*) research by industry
(*f*) technical service to the Colonies
(*g*) cultural Scientific Relations

(*a*) ACADEMIC RESEARCH

Without the basis of fundamental research technical advance becomes sterile and little progress can be made. On the other hand it is possible for great distinction in academic research to be attained at the expense of technical development. It is, therefore, important to establish the optimum ratio between scientific men engaged in applied research and those in the academic laboratories. In the United States this ratio is 4 : 1, in Great Britain 1–2 : 1. The optimum probably lies somewhere between the two.

In normal times the publication and interchange of views on pure research are absolutely free and on an international scale. It is sometimes advocated that national assets in fundamental research should be conserved and that any international schemes of interchange should be discouraged. This could hardly be done so long as academic publication is open as at present, while any attempt to limit the freedom of research workers such as is now threatening in the field of nuclear physics, would immediately result in a deterioration of the quantity of work in a field where freedom of thought and action is essential.

During the war many academic scientists were engaged on extra-mural work of immediate practical and national importance and came to appreciate many technological problems and to be interested in industrial research techniques. It is probable that in the United States at least this type of co-operation may be continued indefinitely.

(*b*) RESEARCH AND DEVELOPMENT MATTERS RELATING TO DEFENCE

This has been the chief activity on which Scientific Liaison Officers have been engaged during the war. It is not possible as yet to forecast the extent to which this liaison will be continued during peace since it depends on political conditions, international agreements and the terms of reference of the supreme international bodies now being set up. It might, however, be agreed that all research has a military significance. Practically all materials, all chemical processes and all physical principles have their importance in military material and in the design and construction of instruments of war, while even agriculture, geology and entomology are deeply involved. Since it would be undesirable for the Services in peace-time to devote undue effort to fundamental research, arrangements will be necessary whereby the fruits of civilian research, in fields such as plastics, metallurgy, rubber technology, radio development, chemotherapy and many other matters can be fed into the Service research stations.

(*c*) GOVERNMENT-SPONSORED CIVILIAN RESEARCH

This provides the type of information which might conveniently form the basis of immediate post-war exchange among the countries of the British Commonwealth and between these countries and Allied powers, for it is in this field that there is the greatest urgency for exchange and at the same time fewer barriers to its operation.

There is a vast volume of information on research of this type available for exchange not only within the Commonwealth but also internationally, for instance, hygiene, nutrition, meteorology, radar, international biological and medical standards, agriculture, research on common raw materials, etc.

It would be superfluous to describe in this paper the organization and scope of the various branches of civilian research in the countries of the British Commonwealth. A brief account of civilian research projects in the United States is given in appendix (iii).

Practically all the work emanating from the laboratories of the U.S. Government Agencies is readily accessible to British countries, to industrialists as well as to Government representatives, but experience has shown that unless liaison scientists are available to make direct contacts with those engaged in research not only would the reports come in too late to be really useful but they are frequently lacking in the necessary detail and perspective for successful application of the information overseas.

(*d*) COLLECTIVE RESEARCH

One of the main trends in industrial research is towards the establishment of co-operative Research Associations or Foundations, where collective work can be undertaken on behalf of a series of industrial firms either on a national or on a regional basis. This has been particularly the case in Great Britain where, in the period between the two great wars, initiative was taken by the Government for the establishment of a number of Research Associations, each representing a single industry and financed partly by Government funds, partly by contributions from participating industrial firms.

In Canada also a number of industrial research bodies have come into being on a regional basis generally in close association with the provincial universities.

A list of Industrial Research Associations in Great Britain and Canada is given in appendix (iv).

In the United States, collective research is gradually becoming recognized as a necessary type of organization for the smaller firms no longer able to undertake individually the heavy burden of research and development necessary if they are to compete with the larger corporations. Other enterprises are organized either according to industry or regionally. Still another American method of conducting research is that of the research foundations attached to universities for the industrial development of projects arising from researches in the laboratories of these universities. The Director of the Research Foundation of Ohio University states that sixty to seventy universities throughout the whole of the United States are considering the establishment of such foundations.

This field of collective industrial research appears destined to play an increasing role in technology due to the increasing scale and cost of development. It has already become an activity in which international relations could, with advantage, be initiated.

(*e*) RESEARCH BY INDUSTRY

During the war industrial firms in both Britain and America have collaborated closely with their governments and have put much valuable

information at the disposal of those governments, much of this having been exchanged between the two Allies.

With the return of peace, there is naturally much reluctance on the part of firms to pass their information to competitors overseas. On the other hand, certain industries which have to compete with other industries producing alternative materials, for instance in the metallurgical field, are appreciating the benefits of collaborative research.

It is certain that the Commercial Attaché will require scientific advice in connexion with industrial advances, and although this would not be among the chief functions of a Scientific Liaison Officer, he might perform a valuable service in bringing about industrial contacts between the firms in his own and other countries.

In addition there is undoubtedly a great deal of information freely available from non-competitive industries, e.g. housing, coal-gas production and the preparation or use of perishable foodstuffs that cannot be exported (liquid milk, etc.).

(*f*) TECHNICAL SERVICE TO THE BRITISH COLONIES

Most of the Colonies are tropical or semi-tropical and because of the nature of their natural products, many of their technical problems are similar to those of the Dominions and India. At present a potential field exists for the collection of technical intelligence relating to raw materials and basic industries of the British Commonwealth.

(*g*) CULTURAL SCIENTIFIC RELATIONS

The delivery of an occasional lecture and the establishment of close relations with the officials of learned societies will become an important if small part of the activities of a Senior Scientific Liaison Officer. This trend is already noticeable in the activities of B.C.S.O., Washington.

SCIENTIFIC COLLABORATION WITHIN THE BRITISH COMMONWEALTH AND EMPIRE

If it is agreed that friendly collaboration between all countries in technology as in other human activities is an ultimate aim, surely one of the first steps should be comprehensive scientific understanding and collaboration between the constituent units of the British Commonwealth and Empire. Not only are closer relations in science required between the United Kingdom on the one hand and the Dominions and India on the other ; lateral ties between the Dominions are equally important. Furthermore connexions with the United States of America have made it obvious that on many occasions there is much to be gained in negotiation on scientific affairs with foreign countries if the Commonwealth can act as a unit. Whatever arrangements are made for representation abroad should be sufficiently flexible to allow of this on certain occasions and of completely independent action at other times.

In appendix (v) a scheme is outlined for the realization of this aim. Its central principle is that scientific liaison work, if it is to be really effective, must be carried out by a series of specialists each working on his own or closely allied subjects.

THE FOREIGN SCIENTIFIC RELATIONS OF THE COMMONWEALTH

From the experience of B.C.S.O., Washington, it is thought that the appointment of single scientific attachés to Embassies and Legations abroad, while better than complete absence of scientific representation, would not be a satisfactory arrangement owing to the impossibly wide field each one would have to cover. More satisfactory results are to be expected from the collaborative work of a few specialists from each of the Commonwealth countries gathered together in organizations resembling B.C.S.O., Washington, and established in certain regions.

The following is a summary of the suggested Commonwealth Scientific Centres throughout the world :

Location of office	*Region served*	*Notes*
London	Great Britain and Western Europe	Possibly single specialist representatives in Paris and other capitals.
Moscow	Russia and Eastern Europe	As far as conditions allow.
Washington	North America	Sub-office in Ottawa.
Rio de Janeiro	South America.	
Melbourne	Australasia.	
New Delhi	India and adjacent territories.	
Nanking	China.	
Cairo	Middle East.	

It must be realized from the outset that it is not envisaged that any one of the Dominions would be permanently represented in all these offices, nor is it suggested that the complete scheme should be put into effect immediately. It is hoped, however, that the proposals as a whole can be considered at the Official Conference and general agreement be reached in principle so that no matter how great or how little the degree of implementation, each of the countries of the Commonwealth may have full and free use of the information gathered at any given Scientific Office, whether represented directly or not. Although ambitious in scope, the scheme here put forward should not be expensive in operation, either as regards money or man-power, if the Commonwealth countries are willing to act in close collaboration, each country contributing in both ways.

LIAISON AND SCIENTIFIC FOREIGN POLICY IN THE HOME COUNTRIES

There are two main ways in which the interdepartmental activities of the scientific liaison groups of each country can be guaranteed. Either the Liaison Officers of a country can be made responsible to a Committee consisting of representatives of various Government departments, in which case the Committee would be empowered to correspond with any interested Ministry, or the Liaison Officers may be responsible for direct communication with other Ministries. Whichever mechanism is used, a small but

strong organization in the home country will be of paramount importance to the success of any liaison scheme.

The experience of B.C.S.O., Washington, is of value in determining the nature of these home bases. During the war the U.K.S.M. was attached to the Ministry of Production, a central co-ordinating department which enabled direct contact with other Government departments in Britain to be easily achieved. Its peace-time status on the vote of D.S.I.R. and under the general control of the Civil Science Panel should allow this favourable condition to persist. The Scientific Liaison Officers for Canada, Australia, New Zealand, South Africa and India, are on the staffs of the National Research Council, Canada, Council of Scientific and Industrial Research, Australia, Department of Scientific and Industrial Research, New Zealand, and Council of Scientific and Industrial Research, South Africa and India, respectively. Although their work is largely concerned with their own departments they undertake liaison work on matters concerning other Government departments through the medium of the Liaison Office of the National Research Council in Ottawa, and in Australia, New Zealand, South Africa and India, through the Council or Department of Scientific and Industrial Research.

Whatever the organization of the home end of the scientific liaison line may be, it is important to have there an officer thoroughly familiar with the workings of the liaison machinery and able to act for the scientific representatives abroad. In addition, he should be responsible for keeping his colleagues abroad well posted on changes of organization and programme, and should himself be a sufficiently good scientist to provide the necessary background of information for a clear presentation of the questions involved.

RECRUITMENT OF STAFF

One of the greatest problems of organization in the establishment of a Commonwealth or international system of scientific relations would be the recruitment of personnel. It is essential that the men chosen should be scientifically of high calibre and at the same time of suitable general experience and personality. It is recommended that in general the scientific liaison officers should be young men in the age group 28–40, specialist research workers who would be seconded for work abroad for periods of not less than six or more than twelve months before returning to the research bench. For the preservation of continuity the senior man should be more permanent. This is a much more difficult position to fill since it demands high administrative and personal qualities as well as scientific experience and energy.

The success or failure of the organizations proposed will depend finally on the quality of men attracted, and it will be one of the duties of the committees responsible for the organization in each country to give serious consideration to the type of man to be recruited.

SCIENCE IN THE UNITED NATIONS ORGANIZATION

At the date of writing (February 1946) considerable discussion has already taken place in the operational agencies of U.N.O. as to exchange

of scientific information in various fields. The Food and Agricultural Organization, U.N.E.S.C.O., and the Atomic Energy Commission will all be responsible for the interchange of scientific information. In addition, other agencies already, or about to be, formed are deeply concerned in particular aspects of science and technology.

It seems as if two separate methods of scientific relation between nations are being planned (*a*) national, i.e. through scientific attachés and national agencies and (*b*) international, through U.N.O.

It is too early in the evolution of U.N.O. to suggest a single scheme which will serve both ends, but since the technical burden within U.N.O., at any rate during the initial and critical period of its existence, will have to be borne by the technically advanced nations, it is appropriate that this problem should be faced, if only in a preliminary way, at the Imperial Scientific Conference. The national scheme put forward here is capable of projection into the international sphere.

Appendix (i)

ANALYSIS OF LIST OF INTERNATIONAL SCIENTIFIC CONGRESSES HELD BETWEEN 1930–1940

subject	no. of organizations effective	no. of meetings held 1930–1940
General Scientific Congress	37	87
Physics	32	56
Engineering and Industrial Research	77	155
Chemistry and Chemical Technology	24	63
Geography and Geology	19	35
Medical	156	336
Biological and Agricultural	77	192
Anthropology and Psychology	32	51
Total	454	975

Appendix (ii)

B.C.S.O., WASHINGTON—DETAILS OF OPERATION

Common Services Section

The following are among the chief services which this section offers to all the constituent missions :

(*a*) A Visits Bureau is maintained which obtains clearances for British and Dominion visitors to United States laboratories, arsenals, etc., for which Army and Navy permission is required. It also makes travel arrangements, internal and international, by air, sea or rail, as well as hotel reservations, etc.

(*b*) A central index of contacts with scientific institutions and individual scientists throughout the United States is being assembled on a

punch-card system to be available as a central directory of specialized American work.

(*c*) B.C.S.O. maintains a comprehensive library of British, Dominion and United States technical reports. These are made available to the various officers of B.C.S.O., to an extent which varies according to the research facilities of the country from which the man has been posted and in conformity with security arrangements.

(*d*) The library staff also undertake the routine distribution of American reports which are allocated to the various scientific missions according to distribution lists compiled after specific negotiations with the United States authorities. This office also serves as a distribution centre in the United States, of technical reports from the United Kingdom and sometimes from the Dominions. The B.C.S.O. library is not a centre of distribution of United Kingdom reports to the Dominions and *vice versa*, that being a matter more appropriate for London than Washington.

(*e*) The Common Services Section arranges for the duplication of documents, the providing of auxiliary stenographic assistance and the provision of a dictaphone service.

(*f*) A bureau for the purchasing of scientific books, journals, publications and pamphlets in open publication, including Congressional Hearings.

(*g*) The purchase of scientific apparatus, research chemicals, biological materials, etc.

Appendix (iii)

Civilian Research in the United States of America

(*a*) *Government-sponsored Research*

In the year 1936–37 some $120,000,000, i.e. some 2 per cent of the total national budget, was spent on research in the United States of America, and still more will be spent in the years following the war. Of this expenditure roughly one-fifth was allocated to Service Research, one-third to Agriculture, one-tenth to the work of the Department of the Interior and one-tenth to the Department of Commerce. Altogether there were some 121 different Federal units engaged in research under the following departments :

(i) *The U.S. Department of Agriculture*, which conducts research not only into all aspects of agriculture and animal husbandry but also into the industrial possibilities of agricultural products and by-products. It has in addition a Forest Service with a vast programme on the utilization of forest products.

(ii) *The Department of Interior*, which maintains the Geological Survey, the Bureau of Mines and the Fish and Wild-life Service. The Bureau of Mines is particularly interested in the utilization of coal, petroleum and natural gas. Much technical work has also been made available for the benefit of the smaller mineral industries.

(iii) *The Department of Commerce* which maintains the Civil Aeronautics Administration and the National Bureau of Standards. It has also set up a Technical Division directly attached to the Secretary's office. This Division has taken over certain war-time agencies such as the National Inventors' Council and the Office of Production Research and Development. The Secretariat of the Interdepartmental Committee on Publication is also located in this Division.

(iv) *The National Advisory Committee for Aeronautics*, which conducts an ambitious research programme on all aspects of aeronautical science, including materials.

(v) *The National Institute of Health* and the *Public Health Service*, which are responsible for most of the medical research undertaken by the Government.

(vi) *The Tennessee Valley Authority*, which is another Government agency responsible for a considerable volume of research which is freely available to all wishing to make use of it.

(*b*) *Industrial and University Research*

As a result of the increasing scale and cost of development work the field of collective industrial research appears destined to play an increasing role in U.S.A. technology. The work may be organized either according to industry or regionally. As examples of the former may be quoted the Pulp and Paper Institute at Appleton, Wisconsin, and the Textile Institute ; amongst the latter, the new California Industrial Research Association.

Other bodies engaged in co-operative research include the Carnegie Institution, the Mellon Institute and the Battelle Memorial Institute, the last two being examples of organizations which undertake to do research for firms under conditions of commercial secrecy. While the results of such researches are not freely available a proportion can be investigated with the permission of the owners and in addition such institutes undertake a certain amount of general technical research not industry-sponsored.

Another American method of conducting research is that of the research foundations attached to universities for the industrial development of projects arising from researches in the laboratories of these universities. These foundations, amongst the better known of which are those of the universities of Wisconsin, Purdue and Ohio, are run for profit and many of them undertake work for particular firms. The Director of the Research Foundation of Ohio University states that sixty to seventy universities throughout the whole of the United States are considering the establishment of such foundations.

Appendix (iv)

Industrial Research Associations in Great Britain *

British Baking Industries Research Association.
British Boot, Shoe and Allied Trades Research Association.
British Cast Iron Research Association.

* In April 1946.

British Coal Utilization Research Association.
British Colliery Owners' Research Association.
British Coke Research Association.
British Cotton Industry Research Association.
British Electrical and Allied Industries Research Association.
Research Association of British Flour-Millers.
* British Food Manufacturing Industries Research Association.
Gas Research Board.
British Internal Combustion Engine Research Association.
British Iron and Steel Research Association.
British Jute Trade Research Association.
† Federation of Lace and Embroidery Employers' Associations (Research Council).
British Launderers' Research Association.
British Leather Manufacturers' Research Association.
Linen Industry Research Association.
Parsons and Marine Engineering Turbine Research and Development Association (Pametrada).
Motor Industry Research Association.
British Non-Ferrous Metals Research Association.
Research Association of British Paint, Colour and Varnish Manufacturers.
British Paper and Board Industry Research Association.
British Pottery Research Association.
Printing and Allied Trades Research Association.
Production Engineering Research Association of Great Britain.
British Rayon Research Association.
British Refractories Research Association.
Research Association of British Rubber Manufacturers.
British Scientific Instrument Research Association.
‡ Scottish Shale Oil Scientific and Industrial Research Association.
British Shipbuilding Research Association.
† Coil Spring Federation (Technical Committee).
British Welding Research Association.
Wool Industries Research Association.

The Associations listed above are under the aegis of the Department and in most cases are grant-aided. In addition to these, however, there are certain other industrial organizations for co-operative research, e.g. British Wrought Iron Research Association, British Rubber Producers' Research Association, Permanent Magnet Association.

* Formed in April 1946 by the amalgamation of the former British Association of Research for the Cocoa, Chocolate, Sugar Confectionery and Jam Trades and the former British Food Manufacturers' Research Association. Included in the Department's Food Investigation Organization.

† Industrial research is carried out on a co-operative basis by this organization, which, for the purposes of the Government Scheme of Industrial Research, is regarded as equivalent to a Research Association.

‡ Not in active existence.

Industrial Research Associations in Canada

The following industrial research bodies have come into being on a regional basis :

Alberta Research Council.
British Columbia Research Council.
Ontario Research Foundation.
Pulp and Paper Institute, Montreal.

Appendix (v)

Suggested scheme for collaboration within the British Commonwealth and Empire

It is suggested that a British Central Scientific Office should be set up in London at the earliest possible date with all the various scientific missions, together with representatives appointed by the Colonial Office, grouped in one building, located if possible near some important technical information centre of the Government of the United Kingdom such as the Department of Scientific and Industrial Research, and also near the offices of the High Commissioners for the Dominions and India.

The routine business of the Office could be run by a small permanent secretariat controlled by the heads of the constituent missions and paid by contributions from the various governments in much the same way as the machinery of the Imperial Agricultural Bureaux is maintained. This common secretariat would supervise the running of registries, provide emergency secretarial and clerical help, duplicate papers, maintain libraries, purchase and transmit published reports and other documents, make travel arrangements, purchase and despatch technical samples, etc. It should preferably be in the charge of a senior administrative man with some scientific background who might also have a general overseeing responsibility for the staff of the *secretariats* of such British Commonwealth scientific offices as were established in Empire capitals and throughout the world.

Each Dominion, as well as India, would provide one scientist or more to the B.C.S.O. (London), chosen in such a way that collectively they could cover the greatest possible area of the field of technology.

It would be understood that while information obtained on a technical subject would generally be made available to all the national sections within the office, each office would be absolutely independent and at liberty to make inquiries of interest to that country only.

Under this scheme a total of about a dozen or more scientists would be available at little cost to any single country. It is suggested that they should be specialists in direct touch with the research laboratories, Government, University and industrial, throughout Great Britain.

The United Kingdom might also appoint to this office one or more part-time liaison scientists, in particular a member of D.S.I.R., to help the scientific liaison officers to obtain the required information. Accommodation would also be provided for temporary specialist visitors and for United Kingdom liaison officers home from abroad on ' refresher ' visits.

The senior scientist in each mission would also carry the responsibility of Scientific Adviser to his High Commissioner with whom he should be in close touch. The office could also provide the Dominion representatives on the Council of the Imperial Agricultural Bureaux thus effecting closer contact with that body.

In order to co-ordinate activity throughout the Commonwealth it is recommended that small Commonwealth scientific offices be established in Australia, South Africa and India. The general link with the rest of the Commonwealth would enable countries not represented directly to ask questions and obtain answers through the medium of the other liaison officers. The senior scientist of each country in the Dominion B.C.S.O.'s would, as in London, act as Scientific Adviser to his High Commissioner.

The establishment of a B.C.S.O. for Canada is not recommended on the grounds that scientific representation should be on a regional rather than on a political basis. Similarly New Zealand could be covered by visits by the scientists from the Australian B.C.S.O.

A further link in the organization would be the appointment in each Crown Colony, mandated territory, etc., of a scientific correspondent, who would normally be a scientist designated by the Governor.

Such a system need not in any way prevent direct correspondence between official scientists in the various countries, but it was found in B.C.S.O. (Washington) that the services provided soon became known to such an extent that in most instances the Mission was used.

It is also suggested that small conferences of official scientists could be called occasionally, meeting in turn in the different capitals of the Commonwealth under a chairman provided in rotation by the constituent countries, to discuss the broader economic aspects of technical problems which might not be immediately apparent to the scientists intimately concerned in the individual countries.

Appendix (vi)

Scientific liaison Offices in relation to general representation abroad

Figure 1 illustrates how a British Commonwealth Scientific Office in an important centre such as Washington could fit in with the other representatives of Great Britain and the Dominions. It is assumed in the diagram that responsibility for liaison on weapons of defence will in peace time revert to the Service Attachés.

In some cases it may well be desirable to appoint Agricultural Attachés, as has already been done in Washington by Great Britain and South Africa. These men might work within B.C.S.O. without loss of Embassy status and contacts. They would then reap the benefit of close attachment both to the Embassy and to B.C.S.O. with its possibilities of specialist advice.

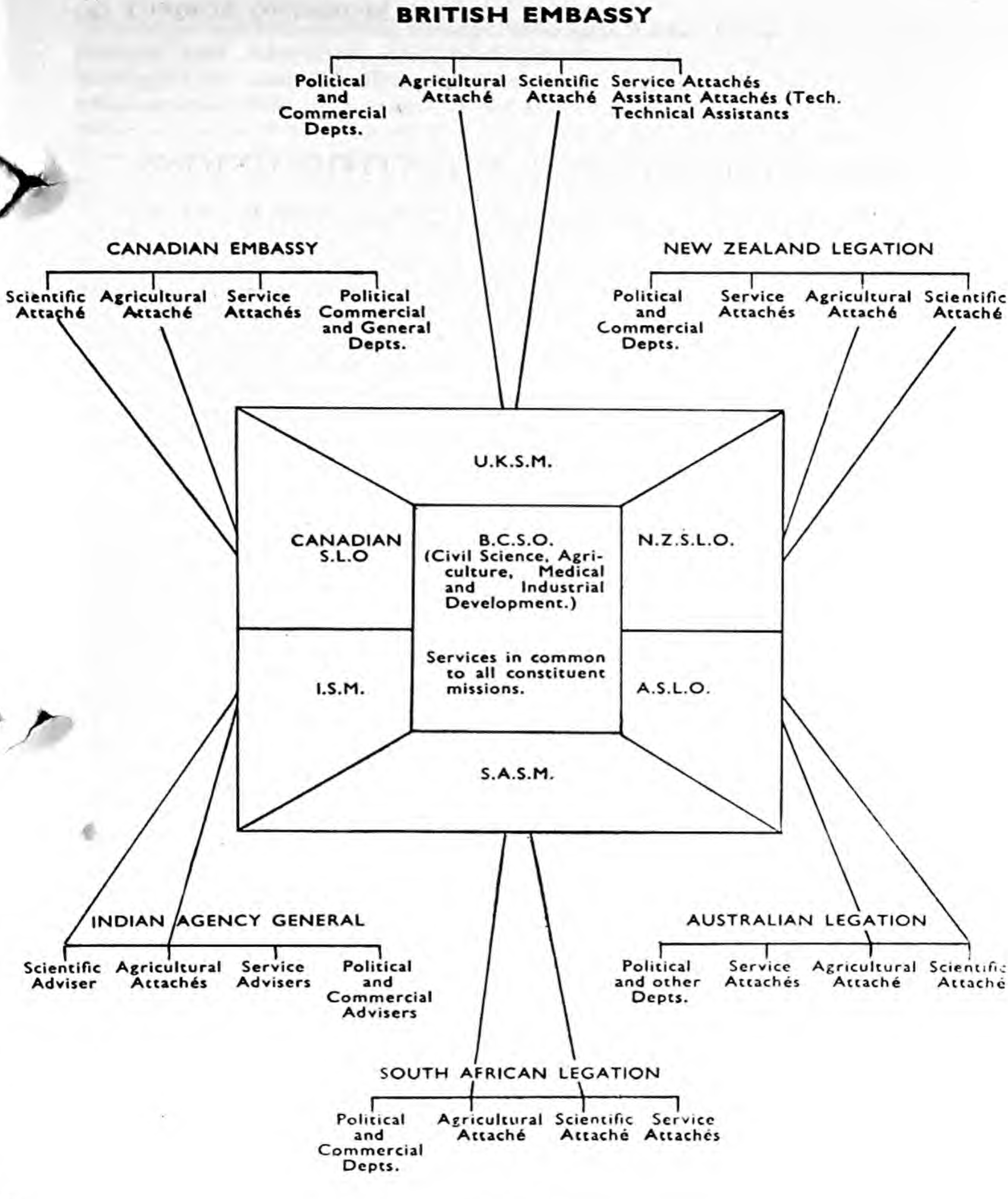
BRITISH EMBASSY
Political and Commercial Depts.
Agricultural Attaché
Scientific Attaché
Service Attachés
Assistant Attachés (Tech.
Technical Assistants
CANADIAN EMBASSY
Scientific Attaché
Agricultural Attaché
Service Attachés
Political Commercial and General Depts.
NEW ZEALAND LEGATION
Political and Commercial Depts.
Service Attachés
Agricultural Attaché
Scientific Attaché
U.K.S.M.
CANADIAN S.L.O
B.C.S.O. (Civil Science, Agriculture, Medical and Industrial Development.)
N.Z.S.L.O.
I.S.M.
Services in common to all constituent missions.
A.S.L.O.
S.A.S.M.
INDIAN AGENCY GENERAL
Scientific Adviser
Agricultural Attachés
Service Advisers
Political and Commercial Advisers
AUSTRALIAN LEGATION
Political and other Depts.
Service Attachés
Agricultural Attaché
Scientific Attaché
SOUTH AFRICAN LEGATION
Political and Commercial Depts.
Agricultural Attaché
Scientific Attaché
Service Attachés

Figure 1

THE INTERNATIONAL SCIENTIFIC UNIONS

By Professor F. J. M. Stratton, D.S.O., O.B.E., M.A.

One of the first, if not the first, example of international co-operation in modern science was a plan for a general survey of the heavens initiated by Bessel in 1824 and warmly encouraged by the Berlin Academy. This was typical of the many international scientific schemes projected during the following ninety years—most of them arising from the drive of some enthusiast and officially sponsored by one of the great national academies. By 1914 astronomy alone had developed thirty-two separate organizations, chemistry had five international societies and such other bodies had been established as the Bureau International des Poids et Mesures, the International Geodetic Association and the International Seismological Association. The only non-specialized body which either controlled or organized international co-operation in science was the International Association of Academies which was founded in 1900 and met every three years up to the outbreak of the European war in 1914. Unfortunately a political element crept into the activities of the association, arising partly from the fact that Germany was represented by five academies—Berlin, Göttingen, Heidelberg, Leipzig and Munich—which were apt to speak and vote as a single *bloc*, while most other countries had only one national academy. It was an inevitable result of previous German domination that, when discussions began at an inter-allied conference on international scientific organizations held in London at the invitation of the Royal Society on 9 October 1918, resolutions were passed that the allied nations should withdraw from the existing international organizations. At the same time it was agreed that new bodies should be formed by the allied nations, which the neutral countries should be invited to join. The war was still in progress and there could be no question of inviting the enemy countries. A second meeting was held in Paris in the following month at which a plan for the establishment of an International Research Council, which had been submitted by the National Academy of Sciences of the United States, was adopted. The scheme included the formation of international unions in the major scientific fields under the auspices and general administrative control of the Council, the various national sections of the unions to be co-ordinated by the national research councils or academies. Finally at a conference in Brussels, 18–28 July 1919, at which twelve countries were represented and a wide range of scientific interests, the International Research Council and the Unions of Astronomy, of Geodesy and Geophysics, and of Chemistry were inaugurated.

The statutes of these unions, based largely on a set of draft statutes drawn up by the astronomical section for the International Astronomical Union, were agreed upon and draft statutes were adopted provisionally

for Unions of Mathematics, Physics, Scientific Radio, Geography, Geology, Biology and Medicine and Bibliography. The Unions of Geology, Bibliography and Medical Sciences were never established, that of Mathematics died as a result of political troubles. The activities of the other unions will be discussed later in this paper. But first some account must be given of the relations of the unions with the Council, particularly in connexion with the struggle to admit the former enemy countries or Central Powers, to membership of the unions. The unions were completely free to manage their own affairs in accordance with their own statutes once these had been approved by the General Assembly of the Council. One statute that was generally adopted by the unions was that the admission of new members was subject to the regulations of the International Council. Unfortunately at the second meeting of the Council in 1922 a proposal was adopted for administrative reasons that any country wishing to join a union should previously become a member of the Research Council. When in 1925 Norway, voicing the views of most of the neutral countries which had meanwhile joined the Council and the unions, proposed that the Central Powers should be invited to join the union, the motion was lost despite the support given to it by Great Britain and the United States. This caused wide dissatisfaction especially among the unions who were beginning to feel their strength and at the same time were growingly anxious to arrange full co-operation with scientific colleagues from among the Central Powers. Under pressure from the Royal Society a special meeting of the General Assembly was held in 1926 and the proposal to admit the Central Powers was adopted by a large majority. But mischief had been done by the drawn-out battle and to this in large part must be attributed the decision of the Union of Mathematics in 1932 to disband itself in favour of the simpler organization of a congress meeting informally from time to time. It should be noted that the Central Powers joined some of the unions.

The original statutes of the Council and unions were under the 1919 convention to be revized in 1931 and at the meeting in 1928 Great Britain proposed changes of statutes to give more freedom to the unions. A committee was appointed with Sir Henry Lyons as Secretary to consult the unions and adhering organizations about desirable modifications, while the unions were allowed to modify their statutes, subject to ratification by the Executive Committee of the union. Sir Arthur Schuster, who had been General Secretary since 1919, retired in November 1928 and was succeeded by Sir Henry Lyons, and to him mainly must be credited the changes in the statutes of the International Council of Scientific Unions, which in 1931 replaced the International Research Council. The chief changes lay in the transfer of executive power from the national adhering organizations to the unions; these latter are now directly represented at the General Assembly and through their representatives they form the large majority of the Executive Committee. The unions are now also free to admit as members countries that do not adhere to the Council. The Council has become rather more of an advisory body, concerned with the organization of fresh international activities especially in fields of knowledge of common interest to two or more unions. Such subjects as 'the relation of solar and terrestrial phenomena' have been

made the study of a committee appointed in the first instance by the Council ; this committee should, I feel, pass over as a joint commission to the Unions of Astronomy and Geodesy and Geophysics. Another committee appointed at the last General Assembly of the Council in 1937 was one on 'science and social relations,' which, within the field of scientific activity, was charged with preparing 'a survey of the most important results obtained and of the directions of progress that are opening and of points of view brought forward in the physical, chemical and biological sciences, with reference to :

'(i) their interconnexion and the development of the scientific picture of the world in general ;

'(ii) the practical application of scientific results in the life of the community.'

It will be obvious to all how seriously the work of this committee has been cut across by the years of the war and the secrecy which has necessarily covered so much recent scientific development.

Now let us turn from this historical account of the unions in relation to the International Council to an account of the work that they carried out in the years 1919–1939. The Astronomical Union gathered together into one body some thirty-two independent organizations and arranged to carry on their work through a number, now thirty-four, of standing committees which could work on continuously, if necessary, between triennial meetings of its General Assembly and would report every three years to the Union. Although some of its members, with a wide range of interests or of official responsibilities, may find the meetings too crowded, there can be little doubt that that drawback is altogether outweighed by the advantage of combining a number of scattered meetings into one, by the overall diminution of time and money spent on administration and by the great advantages from the personal contacts secured at the gatherings of astronomers working in all branches of the subject. The importance of a permanent bureau controlling affairs between triennial meetings was illustrated this year when the Executive Committee was able to arrange for the continuance or restarting of certain activities which the collapse of Germany had brought to an end. Of the continued usefulness and need of the International Astronomical Union there could be no doubt.

The same can be said of the International Union of Geodesy and Geophysics with its seven sections for geodesy, meteorology, seismology, atmospheric electricity and magnetism, physical oceanography, vulcanology and scientific hydrology. The need for international co-operation in these subjects is obvious and in some cases such as geodesy had been recognized by the formation of international associations long before the existence of the Union. An interesting recent development is the formation of a committee on the social value of the earth sciences 'with the object of preparing a general statement on the value of the earth sciences for human welfare and of instituting such other forms of publicity as may from time to time be desirable.' In such a subject as meteorology, although much of the active co-operation must be arranged by directors of government services, there is much to be done by a purely scientific organization

both in stimulating and directing research and in representing to the governments concerned lines of development calling for active study. The same applies to the Union of Scientific Radio. Here again much must be settled by discussion between responsible government authorities as in the matter of the allocation of wave-lengths. But much remains for study and action along purely scientific lines ; frequency standards, ionospheric changes, atmospherics, ultra-short waves may be mentioned as among the subjects allotted to commissions of the Union and recent developments suggest that a joint commission should be formed with the Association of Meteorology to study a number of problems of joint interest.

The Union of Geography is another one with patent international needs. This Union meets alongside the International Geographical Congress, which had existed for many years previously, but it differs from the Congress in keeping active between the meetings of its General Assembly : this it does by means of a central bureau and of international committees, which prepare reports for the following meeting. This may prove to be the simplest method in other cases where established international congresses exist without any international organization active between the congresses. The need of a recognized international specialist body available in any large field of knowledge to advise such an organization as UNESCO (the United Nations Educational, Scientific and Cultural Organization) points to the need of some such development in a large number of subjects.

With the next union, the International Union of Chemistry, we pass away from subjects inherently international ; here too, however, international co-operation has been found both helpful and essential and the Union has through its various standing committees issued annual tables of constants, atomic weights, physico-chemical data and has tackled the questions of nomenclature in inorganic and organic chemistry and in biochemistry. Apart from its purely technical activities the Union has turned its attention to the social aspects of chemistry, such as nutrition, housing and clothing, with a view to making clear to the public and to governments what help they may expect from chemistry.

The International Union of Pure and Applied Physics has not managed to arouse the same interest or general activity as the Union of Chemistry. Its activities have been mainly concerned with questions of international standards in electricity and thermodynamics. The physicist appears to have been more of an individualist than many of his scientific colleagues and until the recent war, except inside single laboratories, the idea of tackling problems jointly by teams seems to have been against his general outlook. One cannot but regret that the International Commission on Atomic Energy should have come into existence with a background of politics and atomic bombs instead of as a normal development of the activities of an international union.

Curiously, like the difference between the two Unions of Chemistry and Physics, has been the difference between the botanical section of the Union of Biological Sciences and the other sections originally projected—general biology, physiology, zoology, medical science, applied biology and oceanographic biology. The latter seem never to have got properly started ; the former attaching itself to and indeed supporting financially

the International Botanical Congress has found useful and important work to carry out. In particular it was deputed by the Congress to carry out resolutions passed by the Congress such as arranging for free transport for scientific collections sent in exchange between botanic gardens. Questions of nomenclature, urgent taxonomic needs, preparation of an index of plant science periodicals and of a geobotanical map of Europe are amongst the problems allotted to standing committees of the Union. It is possible that the botanical section of the Union of Biological Sciences has found the best way of linking an organized union, with its continued existence between meetings, with the more informal International Congress.

Of the present position and future developments of the unions it is difficult to say much at present. They have begun to renew activities after a period of very limited opportunity for co-operation, and most of them have held or will shortly hold meetings of their executive committees, supplemented by a number of delegates from the more accessible countries. One point that has come up from several unions to the International Council is a request for the latter to relieve the unions of their main financial burdens by taking responsibility for the financing of well-established or permanent international services of a substantial nature, while leaving the scientific control with the unions themselves. This would set the unions free to develop new lines of activity without making their budgets too heavy. Such a change is closely linked with the question of the relation to be established between the International Council and UNESCO. At the meeting in London last November at which UNESCO was established it was agreed, on the motion of the delegates from the United States, that the Preparatory Commission should invite its Executive Committee to examine with the International Council of Scientific Unions methods of collaboration which might help the programmes of the two bodies within the spheres of their common interests. At the time of writing * there is nothing to report on the probable developments of this collaboration but it is hoped that a scheme may be drawn up in time for submission to the General Assembly of the International Council in July and to the next full meeting of UNESCO later in the year. On the issue of these negotiations may depend a number of important developments for the various International Unions but still more perhaps the future of the International Council.

* Early April 1946.

MORNING SUBJECT (h)

DISCUSSION OF MEASURES WHICH MIGHT BE TAKEN TO SECURE GREATER UNIFORMITY IN PHYSICAL STANDARDS OF MEASUREMENT AND THE USE OF UNITS, TERMS AND SYMBOLS. (NOTE : THIS IS OF URGENT IMPORTANCE NOW AND IS VITAL FOR THE EFFECTIVE DEVELOPMENT OF INTERNATIONAL CO-OPERATION IN SCIENCE)

Steering Group

Chairman—Dr E. Marsden, F.R.S.

Recorder—Dr J. C. Evans

Sir Charles Darwin, F.R.S.
Dr C. J. Mackenzie
Sir John Madsen
Professor P. C. Mahalanobis, F.R.S.
Dr S. Sambursky
Professor B. F. J. Schonland, F.R.S.

Report

The discussion opened with a review of the present state of the principal standards, and went on to consider the need for eliminating the present slight differences in the values of the British and American Yard and Pound (lb). It was recommended that discussions should be pursued with the authorities concerned in the U.S.A., and the Conference agreed that the Director of the National Physical Laboratory, Sir Charles Darwin, should act in this matter on behalf of the various national laboratories of the Empire.

The Conference discussed the need for maintaining scientific liaison on standards. It was felt to be desirable that the Dominions and India should participate in the international organization, the Convention du Metre, and that meetings of representatives of the national laboratories in the Empire should be held periodically, to consider the maintenance of uniformity of standards of measurement, programmes of research, and the interchange of personnel.

Consideration was given to the need for organizing within the Empire a service of radio transmissions at standard frequencies, which, with those of the U.S.A., would suffice to meet the needs of the Empire. Several speakers endorsed the view that such a service would be of the greatest value. It was agreed that a statement of the present position and of the practical methods of providing standard frequency transmissions should be prepared for the benefit of the various Empire countries.

The importance of uniformity in the terminology used in scientific textbooks and journals was emphasized, and the Conference adopted a recommendation that this question should be actively pursued both in the Empire and internationally.

An interesting and stimulating contribution to the discussion was made by the former Director of Biological Standards at the National Institute for Medical Research (U.K.), who described how, in the inter-war period international acceptance of thirty-five standards and twenty-eight units of activity for use in biological measurement had been achieved. This provides for the accurate dosage throughout the world of such products as penicillin, insulin and vitamins.

The Conference indicated that it would welcome the introduction of the metric system though recognizing the special difficulties of adopting such a change in certain fields. The Conference considered that the trend should be in this direction, and advocated the writing of textbooks in a form which would meet the needs of a reader conversant with either the British or the Metric system.

1. (a) It is considered highly desirable that early steps should be taken to eliminate the slight difference in the values of the yard and pound at present in use in the Commonwealth and in the United States of America.
   (b) It is recommended that discussions should be pursued with the appropriate authorities in the U.S.A. with a view to reaching mutual agreement on this question (as a basis of recommendations to Commonwealth Authorities) and that the Director of the National Physical Laboratory, Teddington, should act in this matter on behalf of national laboratories in the Commonwealth.

The Conference suggests :—

(i) that the reformed units should be precisely related to the corresponding metric units ;

(ii) that tentative values for conversion factors should be as follows :—

$$\begin{aligned} 1 \text{ yard} &= 0{\cdot}9144 \text{ metre} \\ \text{or } 1 \text{ inch} &= 25{\cdot}4 \text{ mm exactly} \\ 1 \text{ lb} &= 0{\cdot}453\,592\,37 \text{ kg} \\ &\text{or } 0{\cdot}453\,592\,3 \text{ kg} \end{aligned}$$

2. The Conference advocated the adoption of the metric system in all fields of science. Examples of subjects in which an improvement in this respect is desirable are aeronautics and pharmaceutical science.
3. If textbooks and scientific data or memoirs are expressed in systems other than the metric, conversion factors or the metric equivalent should be included.
4. The Dominions and India should participate in the organization of the Convention du Metre.
5. There should be meetings at suitable intervals of representatives of the Commonwealth national laboratories to consider :
   (a) the maintenance of uniformity of standards of measurements ;
   (b) general programmes of research in regard to fundamental scientific standards. The National Physical Laboratory in the U.K. should act as the co-ordinating body. The Conference emphasized the importance of mobility of workers between the various laboratories.
6. Within the Commonwealth there should be organized a service of radio transmissions at standard frequencies which, together with those of the U.S.A., would suffice to meet the needs of the Empire.
7. The United Nations Standards Organization be asked to give consideration to the question of nomenclature and symbols at the international level, taking into account, as far as is practicable, both scientific and industrial usages.
8. The Conference recorded its appreciation of the advances which have been made in the international standardization of biological materials and noted with satisfaction that much of this standardization is now brought on to a physical and chemical basis.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr J. C. EVANS (*Report of the Discussion*)

Agenda for Discussion

The following agenda for the discussion was prepared by the Steering Group :

A. (*a*) Review of present knowledge of standards.
   (*b*) Elimination of present slight differences between the British and American Yard and Pound.

B. Scientific liaison on standards.
   (*a*) Relation to International Conference.
   (*b*) Periodic meetings of representatives of the Commonwealth National Laboratories.

C. Radio Transmissions of Standard Frequencies.

D. Terminology.

E. International Biological Standards.

F. General discussion.

Summary of Discussion

A.1. The discussion was opened by Sir Charles Darwin who, at the request of the Chairman, gave a résumé of his paper on Standards of Measurement, dealing firstly with the present state of our knowledge of the standards and then passing to a consideration of some legal and administrative matters. He drew attention to the present slight difference, amounting to approximately 4 parts in one million, between the British and American yards ; although not serious in general manufacture, this difference had already a practical significance for the best quality gauges. By good chance, the relationship 1 inch = 25·4 mm. (exactly) provided a standard intermediate between the present British and American standards, and he advocated the adoption of this simple ratio in the Empire and in America so as to remedy the present unsatisfactory situation. He had discussed the proposal with Dr Briggs, Director of the Bureau of Standards, and it seemed that the change could be made in America without difficulty. Could we not therefore go ahead with this revision, in conjunction with America, and let the necessary changes in the legislation follow later ? It was necessary also to consider the standards of mass ; here there was no simple ratio to put forward but, nevertheless, he regarded it as important that a common standard, defined by a fixed relationship of the pound to the kilogramme, should be agreed and adopted.

A.2. The Chairman then read the following resolution :

(*a*) It is considered highly desirable that early steps should be taken to eliminate the slight differences in the values of the yard and pound at present in use in the Commonwealth and in the United States of America.

(*b*) It is recommended that discussions should be undertaken with the appropriate authorities in the U.S.A. with a view to reaching agreement on this question and that the Director of the National Physical Laboratory, Teddington, should act in this matter on behalf of the Commonwealth Laboratories.

(*c*) The bases of conversion recommended are :

$$\begin{aligned} 1 \text{ yard} &= 0{\cdot}9144 \text{ metre.} \\ \text{i.e. } 1 \text{ inch} &= 25{\cdot}4 \text{ mm.} \\ 1 \text{ pound} &= 0{\cdot}453\,592\,37 \text{ kg.} \\ \text{or } & 0{\cdot}453\,592\,3 \text{ kg.} \end{aligned}$$

A.3 (1). Speaking in support of the resolution, Mr J. E. Sears said that there must for a long time to come be controversy on the question of Metric versus English Units, but it was quite clear that every effort should be made to remove the present differences between the British and American standards of the yard and pound. There was good evidence for the stability of the metre and kilogramme and it appeared very desirable that there should be permanent numerical ratios between the British and Metric Units rather than fluctuating ones dependent on successive experimental determinations.

A.3 (2). It was understood that those concerned in America would be prepared to take the necessary steps to re-define the yard on the numerical basis of 1 inch = 25·4 mm. exactly, especially if we were prepared to do the same, but no discussions had taken place on the relationship of the pound and kilogramme. The figure 1 pound = 0·453 592 37 kg. would be very close indeed to the mean of the present British and American values and was conveniently divisible by 7, so that the value of the grain would also be represented by a terminating decimal. In his personal opinion however the final 7 had little practical significance and he would prefer to see the figure curtailed to 1 pound = 0·453 592 3 kg. In this way, the figures for both the grain and the troy ounce are reduced to a number of significant digits which is within the possibility of direct experimental realization at the present time. The curtailed figure would mean a very slight diminution in the present values of the British and American units of mass, but the only people likely to be at all concerned were the international bankers who were apt to compute metric-sterling or metric-dollar currency equivalents to a string of decimal places far beyond the accuracy of experimental establishment of the ratio. It would also lead to a more convenient contraction if it were desired to re-define the Indian tola in terms of grammes.

A.3 (3). Referring incidentally to the paper by Professors Mahalanobis and Siddiqui, Mr Sears said he would strongly deprecate any idea of calling the metric units by any than their own names.

A.3 (4). Mr Sears concluded his remarks with the suggestion that in Clause (*b*) of the resolution, the word 'pursued' should be substituted for 'undertaken,' and the Chairman accepted this.

A.4. The Chairman stated, on behalf of New Zealand, that they could without difficulty introduce any necessary changes in the legal definition of the units and standards. Their legislation had been given a form which allowed of the needs of science being served.

A.5. Sir John Madsen, formally supporting the resolution, stated that there should be no difficulty in adopting the proposed changes in Australia. The instructions to their legislators were so framed that they could readily change their definitions so as to come into line with the United Kingdom.

A.6. Professor P. C. Mahalanobis referred to the very strong preference for the metric system which existed in India. There were many difficulties in connexion with the establishment of units and standards in India and at present things were in the melting-pot. He felt however that general scientific opinion was strongly in favour of the metric system and that, as scientists, the delegates would all like to see this system universally used ; if this were the case, then they should say so.

A.7. Professor B. F. J. Schonland confirmed that South Africa would gladly follow the proposed changes and he supported the resolution. He assumed that the resolution did not convey authority to sign but that Sir Charles Darwin would report back to the Empire countries the result of his discussions with the U.S.A.

A.8. Dr C. J. Mackenzie pointed out that the Conference had no authority to execute the changes embodied in the resolution, this being a matter for the various governments. He presumed therefore that Sir Charles Darwin would notify the outcome of his discussions with America to the Dominions who would then take up the question with their governments.

A.9. The Conference agreed the interpretation given by Professor Schonland and Dr Mackenzie and a suggestion by Mr Sears that the resolution could be suitably amended by the Steering Group was accepted.

A.10 (1). Mr T. G. Poppy of the Standards Department of the Board of Trade was invited by the Chairman to contribute to the discussion. He referred to the responsibility of the Board of Trade for the administration in the United Kingdom of the Weights and Measures Acts, in which the definitions of the standards of mass and length were laid down, and emphasized that any proposal to change the standards would necessarily mean an alteration in the Act. Regarding the suggestion in Sir Charles Darwin's paper that an Act of Parliament was hardly the best medium for defining basic standards and that definition by Order in Council would present greater facilities, Mr Poppy agreed that might be so, but an Act of Parliament would still be necessary to authorize such procedure and to repeal the appropriate sections of the existing Acts.

A.10 (2). The Board of Trade were aware that the legal equivalents laid down by Order in Council were no longer exact owing to physical changes in the standards themselves and that inconsistency therefore

existed in the Weights and Measures legislation of the country. They appreciated that the Act of Parliament in which the yard and the pound are defined was placed upon the statute book as long ago as 1878, and that a revised, consolidated and extended Act was overdue. The President of the Board of Trade had, in fact, stated in the House of Commons that he would set up a Committee of Inquiry into the whole field of Weights and Measures administration as soon as conditions within the Board permitted. The definitions of the basic standards and their relationships one with another would be considered by that Committee and the Board welcomed this opportunity for their representative to hear the views of the Commonwealth delegates in the matter. Such views would carry considerable weight not only in the deliberations of the Committee of Inquiry, but also in the Board's consideration of its findings.

A.11. The resolution was then adopted subject to the necessary amendment being made by the Steering Group and it was agreed to place on record the resolution advocating the adoption of the Metric system in all fields of science, which had been proposed by Professor Mahalanobis.

B.1. The Chairman invited the Conference to consider the question of scientific liaison on Standards and invited discussion on the following resolutions :

> That the self-governing Dominions and India should be brought into the organization of the Convention du Mètre either by direct representation or by affiliation through the United Kingdom.
>
> That there shall be biennial meetings of representatives of the Commonwealth National Laboratories to consider :
>
> (*a*) the maintenance of uniformity of standards of measurement
> (*b*) programmes of research
> (*c*) interchange of personnel.

B.2 (1). Mr Sears, at the Chairman's invitation, outlined the purpose and functions of the International Conference. The Bureau International des Poids et Mesures was created under the authority of the treaty known as the Convention du Mètre, dated 1875. Its essential purpose is to set up and maintain ultimate standards of measurement which can be used to ensure a common basis of reference for any country which chooses to adopt them. Its decisions and recommendations are directed towards legalistic ends, but have no legal force in any country unless and until that country so enacts. There are at present thirty-two States adhering to the Convention and the Bureau is supported by the subscriptions of these States on a population basis. The affairs of the Bureau are governed by the International Committee of Weights and Measures consisting of eighteen members ; the Committee meets every two years and a General Conference of all subscribing States is held every six years, at which major decisions are sanctioned and the Committee re-elected.

B.2 (2). The Bureau was originally charged with the duty of establishing and maintaining prototype reference standards of the metre and kilogramme for international use ; with the comparison of other standards with these ; and with other measurements incidental to this work, such as temperature

and barometric pressure. In 1921, the terms of reference were extended to include the electrical units and standards. In addition, the Bureau was charged with determinations of physical constants of which more exact knowledge would help to increase the accuracy of measurement and with the co-ordination of the results of similar measurements undertaken by the other laboratories. For the adequate discharge of its new functions, the International Committee has set up Consultative Committees for Electricity, Thermometry and Photometry, consisting of experts nominated by the Committee and by the larger National Laboratories. Under its present terms of reference the International organization therefore can and does carry out some parts of Mr Cooper's proposed programme. It is doubtful, however, in view of its specifically limited objectives, whether its functions should be extended to cover such matters as fundamental constants like atomic weights or the value of the electronic charge.

B.2 (3). It is possible for a self-governing Colony, or Dominion, either to adhere to the Convention as an independent member or to be affiliated to it through the parent country. At present, of the British Dominions, only the United Kingdom, Canada and Eire are independent members, and the others are not represented. It is obviously desirable, now that they are establishing National Laboratories of their own, that they should be. If they wish for independent membership, the subscription is on a population basis. But, lest this should appear too alarming, say, to India, Mr Sears called attention to the fact that there is an upper, and also a lower, limit to the subscription of any individual country, and the upper limit at present is fixed at 22,500 gold francs per annum. If any of the Dominions, on the other hand, prefer affiliation through the United Kingdom, no doubt this could be arranged if they indicated their wishes through the usual channels.

B.3. Professor Schonland strongly supported the resolutions. For South Africa he thought that adherence to the Convention du Mètre by affiliation through the United Kingdom might be desirable but he was of the opinion that the method of adherence need not be mentioned and that the resolution should end at the word 'Mètre.'

B.4. Sir John Madsen signified his general agreement with the resolutions. As regards interchange of personnel he considered there were grave difficulties in arranging visits of over six months' duration, such as the moving of families in the case of married personnel and questions of superannuation. He thought visits of short periods would be more easily organized, that they would be effective and have good results.

B.5. Professor Mahalanobis indicated that he preferred the original wording of the resolution on adherence to the Convention du Mètre and suggested that this should remain if there were no serious objection. Sir Charles Darwin supported Professor Schonland's suggestion and Professor Mahalanobis then agreed the amendment. Some discussion followed regarding the frequency of the meetings of the representatives of the National Laboratories and it was agreed that the period should not be stipulated.

B.6. Both resolutions were then adopted by the Conference, subject to the necessary amendments being looked after by the Steering Group.

B.7. Sir Charles Darwin directed attention to the need for some responsible organization which could be charged with the duty of working out the details of the proposed meetings of representatives of the Laboratories and Sir John Madsen proposed that a secretariat which would prepare the ground for the first meeting should be elected. The Chairman invited nominations and the following were proposed :

Sir Charles Darwin
Dr C. J. Mackenzie
Sir John Madsen
Dr E. Marsden
Professor B. F. J. Schonland
a representative from India.

It was finally agreed, however, that the details should be left for the attention of the Steering Group.

The Conference then adjourned for fifteen minutes.

C.1. The Chairman asked the Conference to proceed to consider the third item on the agenda and, at his invitation, Dr R. L. Smith-Rose gave the Conference the following outline of the present position in regard to the transmission of standard frequencies by radio.

C.2 (1). With a view to making precision frequency standards available to the technical radio user, it is convenient and practicable to broadcast one or more frequencies, the exact value of which can be stated at or before the time of emission. A limited programme of such standard frequency transmissions was operated from the National Physical Laboratory from early 1937 to September 1939. The widespread growth of radio frequency technique during the past six years has given rise to a world-wide need for the dissemination of such standard frequencies, and active consideration is now being given in the United Kingdom to the best and most economical manner in which this may be achieved. To provide anything more than a very local service it is necessary to take into account the influence of the ionosphere on the transmission of radio waves of various frequencies at different times and seasons.

C.2 (2). For the past few years, the U.S.A. Bureau of Standards have installed and operated for this purpose a special transmitting station near Washington using the call sign WWV. Three transmitters, each with an output power of 10 kW., radiate frequencies of 5, 10 and 15 Mc/s. continuously day and night, while a fourth operates on 2·5 Mc/s. during a limited period at night. The radio frequencies are modulated at accurate audio frequencies of 440 and 4,000 c/s., while in addition superimposed pulses of 5 milli-seconds duration are emitted every second to provide an accurate time interval for physical measurements. All these frequencies are derived by harmonic production from one of the 100 kc/s. standard crystal oscillators maintained by the Bureau of Standards, and the precision of all the frequencies is within 1 part in 10^7 of their stated values. Reliable reception of the signals on one or more of the frequencies from Washington is in general possible at all times throughout the United States, Canada and the North Atlantic Ocean, while intermittent reception is possible at greater distances

C.2 (3). For a corresponding service of emissions from the United Kingdom or elsewhere, a possible series of frequencies could be 3, 6, 9 and 12 Mc/s., but in view of the great congestion of this part of the radio frequency spectrum for long-distance telegraphic and telephonic communication, broadcasting and navigational services, it is unlikely that more than one series of frequencies can be allocated for the dissemination of standard frequencies. Wherever there is a need for this type of service, it is therefore likely that it must be provided on the series of frequencies at present in use, and consultation with U.S.A. will thus be necessary on the question of sharing times of transmissions.

C.2 (4). This sharing of times may well prove to be one of the major difficulties in organizing a suitable service throughout the British Empire. The United Kingdom is not well situated for this purpose ; for although a reliable service could be provided for Western Europe, the Eastern Atlantic, the Mediterranean and North Africa, it would be necessary to use expensive, high-power transmitters in order to provide a suitable service to South Africa, India, Australia and New Zealand. It seems desirable therefore to consider the possibilities of providing additional standard frequency emitting stations in other parts of the Empire, although the more stations that are set up, the more acute becomes the problem of arranging time-sharing programmes. It is understood that Australia and South Africa have already given some consideration to this problem, and an early discussion of the matter would appear to be desirable with a view to arriving at the best and most economical compromise for an adequate Empire service.

C.2 (5). A standard frequency broadcasting service could be established in any of the Empire countries on a self-contained basis, the frequency being standardized by the aid of local time-signals provided from the nearest observatory. Alternatively, one or more crystal clocks could be used for the local frequency standard, these being checked at intervals by direct comparison with the frequency standard maintained in the United Kingdom. Such a comparison could be effected either by selecting pre-arranged times at which the signals from the station in England are likely to be received at a useful strength, or by conducting simultaneous measurements on the frequency of a special radio beam transmission between the two countries. Whether the contemplated standard frequency emission services in the different parts of the Empire are self-contained units or not, it seems very desirable that adequate inter-comparisons of the several frequency standards in use should be made from time to time to investigate their relative agreement and stability.

C.3. The Chairman thanked Dr Smith-Rose and invited delegates to state their views. Sir Charles Darwin said he would like to add to Dr Smith-Rose's remarks the question, 'To what extent is it felt that a world-wide service is really needed ?'

C.4. Sir John Madsen indicated that it was hardly possible to answer this question at short notice and recommended that a statement of the position, such as had been given by Dr Smith-Rose, should be prepared and circulated to the various Empire countries. Australia had been going ahead with the

idea of sending out time-signals using its own observatory and crystal clocks.

C.5. Professor Mahalanobis referred to a technical aspect of the matter. From the statistical point of view, he was worried about the significant differences between the values obtained for the velocity of light in determinations made in different laboratories. These differences might amount to as much as eight times the standard error. A review of results obtained over the years suggested a decrease of the velocity with time, but apart from this there were these significant differences amongst the various laboratories, with similar order differences in other standards or constants, and it was considered that they should be investigated to find out their cause. The differences might not lead to trouble in industry, but was it not important to the metrologist to make an investigation ?

C.6. Professor Schonland stated that it was absolutely necessary to South Africa to have standard frequency emissions. South Africa was a large country which must rely on radio for its communications and a system must be installed at an early date, but he could not indicate the method to be followed.

C.7. Sir Charles Darwin, referring to the question of precision, stated that a precision of 1 in 10^8 was aimed at in the transmission of standard frequencies, but that for ordinary wireless work 1 in 10^6 was sufficient. He asked whether the Canadian delegates could say what precision was attained in the U.S.A. standard frequency transmissions. Dr Field (Canada) agreed that the Canadians used the U.S.A. transmission and was of the opinion that the accuracy of the received signal was 1 or 2 parts in 10^7.

C.8. The Chairman suggested that the Conference should decide whether there was a need for a world service and if that question could be answered, the technical details could be worked out later. The following resolution was then put to the delegates and unanimously carried :

> Within the Commonwealth there should be organized a service of radio transmissions of standard frequencies which, together with those of the U.S.A., would suffice to meet the needs of the Empire.

(*Note.*—Dr Smith-Rose's statement, given in paragraphs C.2 (1) to C.2 (5), has been issued as an Official Conference paper, No 42).

D.1. At the Chairman's request, Professor Mahalanobis opened the discussion on terminology. A standard terminology, he said, would be of the greatest value and it was of the utmost importance that steps should be taken to bring about uniformity in this field. It was necessary that the discussions between different countries should be personal, for he was convinced that written discussions could not be relied upon to eliminate the differences of opinion which always arose in questions of this nature.

D.2 (1). Mr P. Good spoke to the following resolution which had been placed before the Conference :

> That the United Nations Standards Organization be asked to give consideration to the question of nomenclature and symbols at the international level, taking into account, as far as is practicable, both scientific and industrial usages.

It might be helpful, he thought, if he explained that the United Nations Standards Organization had grown out of the Co-ordinating Committee which had been set up during the war to obtain uniformity in armaments, etc. It would meet in London in October next. Within the Commonwealth, there were Industrial standardization organizations in the various Dominions and such a body was now being established by the Government of India. There was, therefore, machinery for consultation both within the Commonwealth and at the international level. It was useful to arrange for Commonwealth discussions to take place just prior to the international discussion so that the views of the various Dominions could be unified and an agreed line of action adopted in advance.

D.2 (2). Mr Good welcomed the resolution which, he thought, would result in placing the work in the right channels. Previously, financial support had been very small, but the organizations now being set up would be much better placed and the adoption of the resolution would be helpful because it would provide adequate justification for time and work to be spent.

D.3 (1). Dr Ellingham, supporting the resolution, drew attention to the danger of attempting the impossible. In connexion with symbols, it must be realized that the number of alphabets was limited and it was not possible to allot a different symbol to each different concept. He referred to the work of the Physical Society, the Chemical Society and the Faraday Society in connexion with the allotment of symbols to the more important concepts in physics, chemistry, thermodynamics and engineering. It had been found that by commencing with thermodynamics a most useful start was realized. It was important to get agreement on the uses of the various alphabets and symbols should be chosen with the needs of the user always well in mind.

D.3 (2). As regards terminology, a new approach had been suggested by the Royal Institute of Chemistry, whereby the definitions of chemical terms would be so stated as to enable their use without ambiguity in a court of law. It was desirable that physicists and chemists should state where they agree on definitions of concepts and also indicate where they disagree. The use of abstract conceptions, e.g., defining an electrolyte as a concourse of ions, should be avoided, a definition on an experimental basis being much better. An experiment on these lines was in progress, but it was too early to say what would result.

D. 4. The Chairman thanked Dr Ellingham for his contribution to the discussion and remarked that the Committee he had mentioned was clearly well qualified for its work. The resolution was then put to the Conference and was adopted.

E.1. The Chairman invited Sir Percival Hartley to speak on the subject 'international biological standards.' A summary of Sir Percival's remarks, which were illustrated by means of a wall chart and samples of the standards available, follows.

E.2 (1). The need for standards of measurement in the biological sciences is being met by the establishment of samples of standard preparations and

the adoption of units of biological activity, defined invariably as the specific biological activity of a given weight of the standard preparation. Since 1920, thirty-five standard preparations, covering a wide variety of drugs and substances of biological importance have received international recognition and, associated with them, twenty-eight units of activity. This large measure of international agreement has been secured by the work of the Permanent Commission on Biological Standardization of the Health Organization of the League of Nations, under whose auspices the standards and units have been brought into effective operation in a great part of the world.

E.2 (2). The work of standardization is based upon measurement of biological properties which can be demonstrated by means of animals. The errors associated with such work are naturally much larger than those of physical measurement ; they arise from various causes, of which animal variation and variation in the form of the dose-response curve are the chief. Research is directed towards the study of such errors and the improvement of technique.

E.2 (3). The availability of the international standards and units has been of enormous help to workers in biology throughout the world and has contributed greatly to the success achieved in researches in infectious diseases, nutrition, pharmacology, etc. Research workers in laboratory, hospital and field, physicians and manufacturers have all benefited by the availability of a universally accepted system of standards and units.

E.3. The Chairman thanked the speaker and suggested that the Conference might wish to place on record its appreciation of the work which had been done in this field of standardization. The following resolution was carried unanimously :

> The Conference records its appreciation of the advances which have been made in the international standardization of biological materials, and notes with satisfaction that much of this standardization is now brought on to a physical and chemical basis.

F.1. No further points for discussion were raised and the Chairman terminated the meeting at 12.30 p.m.

Thirty-nine persons were present.

Mr J. E. Sears

Mr Sears gave a short account of the organization of the Bureau International des Poids et Mesures under the authority of the treaty known as the Convention du Mètre, dated 1875, as amended in 1921. The terms of reference, and the resources, of this organization, are strictly limited. Its essential purpose is to provide and maintain ultimate standards of measurement which can be used to ensure a common basis of reference for any country which chooses to adopt them. Its decisions and recommendations are directed to legalistic ends, but have no legal force in any country unless and until that country so enacts.

There are at present thirty-two States adhering to the Convention, and the Bureau is supported by the subscriptions of these States, on a population

basis. The affairs of the Bureau are governed by the International Committee of Weights and Measures, consisting of eighteen members, each of whom must belong to a different nationality. The Committee meets every two years, and there is a General Conference of all subscribing States every six years at which major decisions are sanctioned, and the Committee re-elected.

The Bureau was originally charged with the duty of establishing and maintaining prototype reference standards of the Metre and Kilogramme for international use; with the comparison of other standards with these; and with other measurements incidental to this work, under which heading come questions, for example, of temperature and barometric pressure. In 1921 the terms of reference were extended to include the co-ordination of measurements relating to electrical units, setting up and maintaining standards for these units and comparison of other such standards therewith. In addition the Bureau was charged with determinations of physical constants of which more exact knowledge would help to increase the accuracy of measurement, and with the co-ordination of the results of similar measurements undertaken by other laboratories.

For the adequate discharge of its new functions the International Committee set up a Consultative Committee for Electricity, consisting of experts nominated by the Committee, and by the larger National Laboratories, to advise them. Subsequently similar Consultative Committees were set up for Thermometry and Photometry.

Recommendations of the Consultative Committees should have come before the International Committee, and subsequently the General Conference, in 1939, but owing to the war this was not possible, and the Committee will meet again for the first time officially in October 1946. The recommendations in question include the proposed adoption of the absolute c.g.s. electrical units in place of the present international units, and of the square centimetre of melting platinum to define the new international candle.

Under its present terms of reference the international organization therefore can and does carry out some parts of Mr Cooper's proposed programme. It is doubtful, however, in view of its specifically limited objectives, whether its functions should be extended to cover such matters as fundamental constants like atomic weights or the value of the electronic charge.

It is possible for a self-governing Colony or Dominion either to adhere to the Convention as an independent member, or to be affiliated to it through the parent country. At present, of the British Dominions, only the U.K., Canada and Eire are independent members, and the others are not represented. It is obviously desirable, now that they are establishing National Laboratories of their own, that they should be. If they wish for independent membership the subscription is on a population basis. But, lest this should appear too alarming, say, to India, Mr Sears called attention to the fact that there is an upper, and also a lower, limit to the subscription of any individual country, and the upper limit at present is fixed at 22,500 gold francs per annum. If any of the Dominions, on the other hand, prefer affiliation through the U.K. no doubt this could be arranged if they indicate their wishes in the matter through the usual channels.

Mr J. E. Sears (*Elimination of the present slight differences between the British and American Yard and Pound*)

Mr Sears pointed out that the primary purpose of any system of weights and measures was to meet the requirements of commerce and industry, including domestic trade. While scientists might have their own opinions as to what was desirable, it was not for them to dictate, but to provide and maintain such standards as were required to meet these needs in the form prescribed by law.

The use of the metric system had been optionally permissible both in the United Kingdom and in the U.S.A. for over half a century, but the amount of use actually made of it in trade in either country was still relatively small and did not afford much encouragement to anticipate a general change-over from the yard-pound system. He had reason to believe that opposition to such a change would be no less strong in American than in British industry.

On the other hand it was quite clear that steps should be taken to eliminate the slight differences at present existing between the British and American standards of the yard and pound. There was good evidence for the stability of the metre and kilogramme, and it was understood that those concerned in America would be prepared to take the necessary steps to re-define the yard on the numerical basis of 1 inch = 25·4 mm. (exact), especially if we were prepared to do the same. This is roughly the mean of the present British and American values, and would mean a change of no more than 2 parts in a million in the value of the yard on either side. It appeared very desirable that there should be permanent numerical ratios established in this way between the British and metric units rather than fluctuating ones dependent on successive experimental determinations.

Unfortunately no simple ratio, like that for the yard and metre, was possible in the case of the pound and kilogramme. So far no steps had been taken to reach advance agreement with America on this point. The figure

1 pound = 0·453 592 37 kg.

would be very close indeed to the mean of the present British and American values, and was conveniently divisible by 7, so that the value of the grain would also be represented by a terminating decimal. In his personal opinion however the final 7 had little practical significance, and he would prefer to see the figure curtailed to

1 pound = 0·453 592 3 kg.

In this way the figures for both the grain and the troy ounce are reduced to a number of significant digits which is within the possibility of direct experimental realization at the present time. This would mean a very slight diminution in the present value of the British and American units of mass—about 1 part in 10 million for the former and 3 parts in 10 million for the latter. The only people who were likely to be at all concerned would be international bankers, who were apt to compute metric-sterling or metric-dollar currency equivalents to a string of decimal places far beyond the accuracy of experimental establishment of the ratio. They might have to be appeased.

The curtailed figure also happens to lead to a more convenient con-

traction if it were desired to re-define the Indian tola in terms of grammes. Incidentally, referring to the paper by Professors Mahalanobis and Siddiqui, Mr Sears said he would strongly deprecate any idea of calling the metric units by any than their own names. It was, he considered, most inadvisable to allocate to them Indian names which at present had even slightly different significances.

Professor M. R. Siddiqui

It is a regrettable fact that a good deal of diversity still prevails in the matter of terminology and notation even among the English writers in fundamental subjects like mathematics and physics. When a subject is being newly created, this diversity is, of course, understandable and in fact unavoidable, but in topics like vector analysis or differential equations which have been established now a long time, this practice leads to much confusion. Sometimes one and the same concept is denoted by different terms and sometimes one term is employed to denote different concepts.

It is necessary, therefore, that some machinery should be set up to ensure uniformity in terminology and symbolism. Perhaps this can best be achieved with the co-operation of the International Congress of Mathematicians, of Physicists and of workers in other sciences. A standing committee may be appointed for each science whose duty it would be to publish periodically an agreed list of new terms and symbols.

MEASURES WHICH MIGHT BE TAKEN TO SECURE GREATER UNIFORMITY IN STANDARDS OF MEASUREMENT AND THE USE OF UNITS, SYMBOLS AND TERMS

By E. R. Cooper, M.Sc., Ph.D.

1. INTRODUCTION

The present position relating to standards, units, symbols and terms is that there are no comprehensive authoritative publications internationally recognized, which are being automatically and continually revised, and giving the present accepted views of scientists working in a particular sphere. The information must either be searched for in a literature frequently confused, or be obtained from non-authoritative books published by individuals.

Many inconsistencies exist even within the one book. The task of sifting the information, judging the merit of any particular measurement, deciding upon the most suitable symbols and nomenclature, is a tremendous task which can only be rendered *authoritative* by mutual agreement between all parties concerned, wherein lies the essential difficulty. Unless such mutual agreement is forthcoming confusion persists. To avoid confusion one must at least attempt the task, the satisfactory performance of which would institute a major advance in the organization of science.

2. INTERNATIONAL COLLABORATION

The International Convention of 20 May, 1875, was one of the earliest attempts at international collaboration in science. The Convention aimed at international uniformity and perfection of the metric system of measurement and is sometimes referred to as the Metric Convention. A constitution was drawn up and signed by representatives of Germany, the Argentine Republic, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Denmark, Spain, the United States of America, Finland, France, Great Britain, Hungary, Italy, Japan, Mexico, Norway, Peru, Portugal, Roumania, the Serb-Croat-Slovene State, Siam, Sweden, Switzerland and Uruguay.

The constitution was modified later by the International Convention of 6 October, 1921.

As a result of the 1875 Metric Convention there was set up in Paris the International Bureau of Weights and Measures housed in permanent buildings and staffed with permanent scientific personnel elected by ballot. The Bureau is maintained by contributions made on a population basis by the participating countries.

The International Bureau is responsible to an International Committee of Weights and Measures of eighteen members which acts under the direct

authority of a General Conference formed by the delegates of the above countries. A set of regulations governing procedure was drawn up by the Convention in which it was laid down that the International Committee of Weights and Measures should meet at least once every two years, and the General Conference should meet once every six years. Thus there have been General Conferences held regularly since 1875 until 1933 at which important decisions with regard to international units have been ratified. These decisions have been accepted as authoritative throughout the world. At each meeting of the General Conference one half of the members of the International Committee terminate membership and eight new members are elected.

The International Bureau of Weights and Measures was charged in 1875 with :—

(i) ' All comparisons and verifications of the new primary standard metres and kilograms.
(ii) ' The preservation of the international prototypes.
(iii) ' The periodical comparisons of the national standards with the international prototypes and their primary copies and of the standard thermometers.
(iv) ' The comparison of the new primary standards with the fundamental standards of weights and measures other than metric in the different countries and in scientific use.
(v) ' The verification and comparison of geodesical instruments.
(vi) ' The comparison of standards and scales of precision, the verification of which may be demanded either by the respective governments, or by scientific societies or even by artists or by men of science.'

The 1921 Convention extended the above work of the Bureau to include :—

(vii) ' The co-ordination of measurements relating to the electrical units . . . the establishment and preservation of standards of electricity and of their reference copies and also the comparison with those standards of national standards or of other standards of precision.
(viii) ' Determinations of those physical constants, a more exact knowledge of which would serve to increase accuracy and better assure uniformity in the spheres to which the above-mentioned units appertain.' The ' co-ordination of analogous determinations carried out in other institutions.'

It is submitted that the International Conventions of 1875 and 1921 created an organization which possesses the necessary official status internationally, and which by its successful co-ordinating of the work of the world's national physical laboratories on the standards of mass, length, time, temperature and electricity has gained the necessary scientific status to enable it to operate in an extended sphere, viz., of establishing greater uniformity in the accepted values of the physical constants and the use of terms and symbols in the exact sciences as well as the units of measurement therein.

Already many international committees exist such as for example :—

The International Union of Physics
The International Union of Pure and Applied Chemistry
The International Geophysical Union
The International Electrotechnical Commission
The International Commission on Illumination
Etc.

The various Scientific Unions were constituted under the ' International Council of Unions ' which had a connexion with the ' Institution for Intellectual Co-operation ' of the League of Nations. The contention however that science is important enough to warrant its own organization in future international collaboration is worthy of close consideration.

The difficulty of keeping track of the decisions of so many international committees is another factor contributing to confusion. One would like to see a co-ordination, through a central ' clearing station,' of the work of these very valuable international committees at least so far as it pertains to those units, symbols and terms which are necessary in fundamental precision measurement. This ' clearing station ' would be required to issue as widely as possible official publications incorporating decisions on—

(*a*) International committees' personnel.
(*b*) Glossaries of terms and symbols pertaining to systems of measurements.
(*c*) Accepted values of the fundamental physical constants,* viz. :—
  (i) velocity of light
  (ii) gravitational constant
  (iii) relation of the litre to the cubic decimetre
  (iv) volume occupied by one gram molecule of a perfect gas at N.T.P.
  (v) atomic weights
  (vi) Absolute temperature zero on the international centigrade scale
  (vii) Joule's equivalent
  (viii) the quantity of electricity necessary to electrolyse one gram equivalent
  (ix) the electronic charge e and the specific charge e/mo
  (x) the Planck constant
  (xi) the Avogadro number
(*d*) Definitions of units of measurements.
(*e*) Fundamental standards of mass, length, temperature and electricity.

Such documents would need to be issued automatically to specified universities, scientific societies and laboratories within the countries contributing to the International Bureau of Weights and Measures. One need scarcely emphasize the importance of keeping university teachers of all countries posted with the latest decisions on these scientific fundamentals.

It would be necessary for the central bureau to participate actively in measurements related to the above ; for experience teaches us that without

* R. T. Birge. 1941. *Reports on Progress in Physics*, **8**

this the bureau would not be able to acquire the necessary expert personnel nor would it be able to maintain the necessary select place in the scientific sphere that would be essential. Many difficulties would be involved at the present time in expanding an organization such as the International Bureau of Weights and Measures. The chief difficulties appear to be :—

(i) The extreme shortage of scientific personnel throughout the world arising from the increased application of science to industry brought about during the 1939–45 war.

(ii) The need for extending buildings at a time when the building of homes must necessarily take precedence.

(iii) The apprehension that may exist among the peoples of the world at any steps taken to share scientific knowledge. Science has now become implicated in international affairs of state through its startling contributions to the war machine.

3. BRITISH COMMONWEALTH COLLABORATION

The most remarkable result in recent years of the scientific activity within the British Commonwealth is the formation by each of the major Dominions of its own 'National Physical Laboratory.' Almost simultaneously India, South Africa, Australia and New Zealand have developed these laboratories, and Canada had taken action some years previously through its Research Council Act 1924.

In New Zealand the Research Amendment Act 1945 charges the Minister for Scientific and Industrial Research with the procurement and custody of every New Zealand standard of measurement. The Department of Scientific and Industrial Research is charged with the following functions, viz.—

(*a*) To maintain all principal standard measures for the time being in the custody of the Minister.

(*b*) To compare principal standard measures with corresponding standard measures outside New Zealand by such methods and at such intervals as may from time to time be prescribed by any act or regulations.

(*c*) To compare with principal standard measures and to certify such copies thereof and such secondary standard measures or denominations derived therefrom as may from time to time be required.

The laboratory performing this work in New Zealand will be the Dominion Physical Laboratory, Lower Hutt, Wellington.

It is essential then to realize that so far as standards of physical measurement are concerned there now exists a group of laboratories within the Empire which provide a permanent channel for unifying the adoption of units of measurement throughout their respective countries. Moreover, it has transpired that the central co-ordinating bureau so far as these British 'National Physical Laboratories' are concerned has been the National Physical Laboratory at Teddington. We in New Zealand are in the initial stages of collaborating with the N.P.L., Teddington, on the matter of standards.

There is an obvious step that can now be taken, viz., to ensure permanent collaboration among the National Physical Laboratories of the Empire, thus securing an effective means for obtaining uniformity in the adoption of standards, terms and symbols relating to fundamental systems of measurement throughout the British Commonwealth. There is also the possibility of these laboratories collaborating over a long term plan for the determination of the fundamental physical constants.

Attention may be drawn here to article 20 of the Regulations of the International Convention referred to in section 2 above, which states that—

> ' If a State, party to a Convention, declares it is desired to extend the privilege to one or more of her Colonies not enjoying self-government, the total of the population of the said colonies shall be added to that of the State in order to establish the scale of contributions.
>
> ' When a self-governing Colony desires to accede to the Convention, it shall be considered, as regards its entry into the Convention, in accordance with the decision of the mother country, either as a dependency of the latter or as a contracting State.'

So far as New Zealand is concerned it would be sufficient for her to be represented in the Convention as a dependency of Great Britain. The point I wish to make further is that if the National Physical Laboratories of the British Empire could be brought into close co-operation by the establishment of the necessary mechanism, then it would be possible for them to be represented conjointly in the International Convention, the General Conference and the International Committee for Weights and Measures and such other international scientific committees as may be considered necessary in obtaining uniformity in physical measurement.

STANDARDS OF MEASUREMENT

By Sir CHARLES DARWIN, K.B.E., M.C., F.R.S.
(Director of the National Physical Laboratory, Teddington)

AT the Imperial Conference of 1930 there was a special Conference on Standardization which reviewed the various units and standards for the Empire. It had two committees, one dealing with the fundamental standards, the other with industrial standardization. The second of these is a very important subject indeed, but it falls outside my field. The first committee expressed wishes under three main headings :

(i) That there should be uniformity for all units in common use in the Commonwealth.
(ii) That each Dominion and India should be provided with suitable reference standards for each unit of measurement required in the country, and that suitable procedure should be introduced for their periodical comparisons with the British standards.
(iii) That at least one member of the Commonwealth should undertake research with the object of enabling the fundamental standards to be referred ultimately to natural standards such as the wave-length of light.

It seemed to me therefore that it might be of some use if I were to review briefly the present state of our knowledge of the standards, touching on the question of which of them seem to call for continued attention. I shall then review some of the legal questions connected with them, and conclude with a discussion of what might be done to bridge the practical inconveniences of having two systems of weights and measures, the British and the metric.

A general view of the present state of the standards was recently given in a discussion * held at the Royal Society in March which is now in your hands. I do not propose to go into this in detail but will remind you of some of the salient facts by drawing your attention to the table on the following page in which the principal units are displayed. In this table most of the columns are self-explanatory, but I had better explain the last two. In determining the value of a standard of length, we compare it with the fundamental standard of length—the prototype metre—and the column 'accuracy of comparison' describes the accuracy with which this can be done—to two parts in ten million. Similarly for a weighing. But when we come to derived units, such as velocity, pressure or current, there are two different types of accuracy. There is here also the 'accuracy of comparison,' as for instance when we compare the electrical resistance of a given piece of wire with a standard resistor, but secondarily there is the 'accuracy of realization,' when we say what the wire's resistance is in absolute ohms derived from the standard metre, kilogramme, and second. This is often considerably more difficult, and must be given a lower accuracy

* *Proc. Roy. Soc. A*, 1946, **186**, 149.

TABLE OF ACCURACIES

unit	physical dimensions	standard or reference	nature	accuracy of realization (parts in one million)	accuracy of comparison (parts in one million)
length	L	international metre	material	—	0·2
		wave-length of light	natural	0·02	0·01 (*a*)
mass	M	international kilogramme	material	—	0·002 (*b*)
time	T	mean solar second	natural	—	0·01
temperature	—	thermodynamic scale	theoretical	— (*c*)	1 (*d*)
volume	L^3	litre (*e*)	derived	1	—
gravity	LT^{-2}	earth's attraction	natural	2	1 (*f*)
pressure	$ML^{-1}T^{-2}$	standard barometer	—	10	—
electric resistance	LT^{-1} (*g*)	ohm	theoretical	10	1
electric current	$M^{\frac{1}{2}}L^{\frac{1}{2}}T^{-1}$ (*g*)	ampere	theoretical	10	1 (*h*)
quantity of heat	ML^2T^{-2}	calorie	—	100 (*i*)	—
luminous intensity	ML^2T^{-3}	candle (*j*)	material	2,000	1,000
sound pressure	$ML^{-1}T^{-2}$	—	derived	10,000	— (*k*)

NOTES

(*a*) comparison of derived end-standards (metre or yard)
(*b*) comparison of kilogrammes
(*c*) the absolute zero is accepted as $-273{\cdot}15 \pm 0{\cdot}02°$ C.
(*d*) reproducibility of the ice-point on the absolute scale
(*e*) derived from the kilogramme of water ; 1 litre = 1000·027 c.c.
(*f*) accuracy of relative comparisons between different stations
(*g*) on the electromagnetic system
(*h*) the relative comparison is not of amperes but of volts
(*i*) electrical determination of J for the 15° C. calorie
(*j*) the dimensions are those of power but there is an additional factor representing the response of the eye to energy at any wave-length
(*k*) the acoustic unit selected is the most generally useful ; the accuracy of comparison varies with the experimental conditions but would generally be better than the accuracy of realization.

for many of the units—indeed it obviously could not have a higher accuracy, for if it did it would supersede the other as being also an 'accuracy of comparison.'

Going briefly through the table we may consider which of them call for more work. As to *length*, the accuracy of 2 in 10^7 is a little better than any practical demands require, but only so by a factor of 5, for if we were to alter the length by 1 in 10^6, though there would be no effect on actual manufactures, some makers of gauges of the very highest class would let us know they were in trouble at once. I shall have occasion later to say more about this. For the standard of length we have the possibility now of a wave-length standard in which a rather higher accuracy can be attained; already the use of interference is normal practice in the most accurate measurements of standards of length. The present limitation is the quality of the spectrum line of cadmium, which reveals a certain faint hyper-fine structure. This difficulty will be overcome probably at no distant date by using a single isotope, even-numbered so as to have no hyper-fine structure. It will probably be mercury as being both convenient and heavy. The weight of mercury reduces the Doppler effect, but even without this, by the use of a transverse beam of atoms, it should be possible to produce a spectral line that is much narrower so that we could use it as a standard a good deal better than anything we have. A rough calculation suggests that we might gain a factor of a hundred or so, but that electromagnetic damping will then give the limit. It is to be desired that we should go as far as possible in this way, define the metre in terms of such a wave-length, and then forget all about the objective prototype standard of length.

For the standard of *mass*, unlike length there is no way of adopting a natural standard. In idea we may imagine the mass of a hydrogen atom as the standard, but it is hard to believe that any standard of this kind could ever in the remotest degree rival the accuracy attainable in the most precise weighings, an accuracy of 2 in 10^9. In passing it may be remarked that at this precision the shape of the weights is beginning to become important, for if one weight is higher than the one in the other scale pan its greater distance from the centre of the earth makes it apparently a little lighter. We may feel that the precision of mass measurement is as good as it need ever be.

The practical interest lies in other directions. It is necessary to make due allowance for air buoyancy when comparing weights, and comparisons in vacuum are not only technically difficult but are affected by consequential changes in the adsorbed films. Corrections for buoyancy are not always easy to evaluate adequately where high precision is involved, and in more ordinary weighings they can and often do lead to a good deal of confusion. Brass weights are of course very frequently used, but the density of the brass is not invariable, so that perceptibly different answers can be obtained. Conventions have been made about this, but they are not the same in different countries, and I believe that the difference can be detected between weighings of gold in England and on the Continent on this account. There is need for a practical convention to settle these matters, but they have little scientific interest.

The standard of *time* is of a different quality from the others, and is primarily a matter for the astronomers, so that I shall only touch on it

briefly. There have been great improvements in recent years in the taking of star-transits, and even greater ones in the design of clocks, in particular of crystal clocks. It is now the case that the clocks over shortish periods can be trusted to show up irregularities in the earth's rotation. There is evidence that this rotation alters discontinuously every now and then, and of course we know that owing to tidal friction it is slowing down all the time. What are we to do about keeping the standard? We might imagine we could use the frequency of a spectral line as a standard, but this is a long way ahead, and its electromagnetic damping would most likely dispose of the possibility. Anyhow we can wait a good many centuries before getting into this trouble, but we may note that unlike length and mass there is still great scientific interest in the study of the time standard.

Closely cognate with time is its reciprocal frequency, and this has much practical interest. Before the war we used at the National Physical Laboratory to send out periodic emissions, on quite a small scale, giving frequency standards largely for the benefit of amateurs. During the war the subject assumed much greater importance, and there has been continual need for the control of the emissions from service wireless equipment. In the meantime the United States have started a continuous emission of standard frequencies from the WWV station near Washington. It gives a service on some five frequencies, at exactly 2·5 Mc/s and multiples, so that within 2,000 miles one or other can always be received, and at various times of day over much greater distances. We have been exploring the possibility of giving a similar service here, which would aim at covering most of Europe, and parts of Asia and Africa. There is the practical difficulty that there are not many frequency bands available, that such emissions ought to be in exact round numbers, and that it would not be convenient for simultaneous emissions from England and America to be on the same frequencies. Negotiations may be possible about this with America to avoid the clash, but it is too early to speak about it. I would like to think, however, that at no distant date it should be possible by four stations or so to have a coverage of the whole earth with standard frequency emission. As to their precision, it is estimated that the emitting stations should find it possible to keep time to nearly 1 in 10^8, but the reception at the more distant stations might lose a factor of 10 or so on account of the Doppler effect of the rising or falling ionosphere.

Coming now to the derived standards, there is no need to say much about that of *volume*, beyond pointing out that the practical unit is not the cubic centimetre but the millilitre, which is defined in terms of a specified mass of water. Here there may be trouble because of the variability of the amount of heavy hydrogen in the water, which might make errors of a few parts in a million.

In determining what may be called the dynamic standards, pressure, energy, etc., the value of gravity plays a very important part so that g may be regarded as an essential intermediary. It can be determined to 2 in 10^6. For the present this is as good as is needed, but there is little to spare, in the sense that an admissible alteration in g would come very near to altering the value of the absolute ampere. Three very careful evaluations of g have been made by the method of the reversible pendulum; it is hard to see how any much closer value could be got out of this method, and it is also

difficult to think of any rival method that could hope to give an answer closer than 1 in 10^6, but we may say that of the problems of fundamental metrology the evaluation of g is one that is still alive. This is for the absolute value. Relative values of g in different places can be determined with an accuracy of 1 in 10^6 without very great difficulty, and it may be for consideration whether they are known sufficiently in various places on the earth.

Derived from g are most of the measures of dynamical units, for example, *pressure*. The most accurately measured pressure is that of the atmosphere. This is known to about 1 in 10^5 ; the measures of the barometric height and of g are rather better than this, and the density of mercury is the difficulty. Here again there may be trouble over variability in proportions of the isotopes, but it is unlikely to be serious in this case.

The statement of the value of a pressure near atmospheric in absolute units seems on the whole to be good enough, but there are troublesome matters calling for agreement on the subject owing to there being different conventions, which may make quite perceptible differences in recorded pressures. For example, the inch scale measures the inches at 62° F., whereas conventionally the mercury is standardized at 32° F. In the millimetre system the scale and mercury are both defined at 0°C., but the measurement is always made at more convenient temperatures, and the relative expansion of the mercury and the scale have to be taken into account. There are in use two different conventions as to the value of g to be adopted. The millibar scale is theoretically the right one for a pressure, but here too there are certain conventions used by meteorologists which are open to criticism. The whole matter is excessively confusing, and calls for unification, and no doubt the only reason this has not already been done is that there are very few people who really demand measures of atmospheric pressure with the highest precision.

Turning now to the *electrical units*, there has been the advantage that they were founded scientifically and therefore are free from troubles about old conventions, and the subject is not complicated by there being a separate list of British units. The measurement of the absolute values is now roughly 1 in 10^5 ; it calls for work of the very highest and most laborious skill, both mechanical and electrical, to construct the mutual or self-inductances that form the basis of the work. It is work which in recent times has been predominatingly done in Teddington and Washington, and it is certainly not work to be lightly embarked on by anyone.

The electrical units raise one interesting point about the principle of standards which goes a little outside my two 'accuracies.' In 1908 the international conference defined as the 'international ohm' the resistance of a column of mercury of uniform cross-section and of specified length and mass. The idea is that one should be able to set up the standard in this way by prescription, but it has been found that if several standards are constructed according to these rules they vary among themselves very perceptibly ; so that if one of them were arbitrarily chosen as *the* standard the rest could be easily distinguished from it. This raises the question of whether such a standard by 'prescription' is really useful, or whether it may not be better to keep a set of high quality wire resistors calibrated at the main standardizing laboratories, and maintain the standard by frequent

inter-comparisons in much the same way as is *essential* for the primary standards of length and mass. At the time, the ' prescribed ' standards were a good deal more accurate than the absolute measures, but there have been great improvements in these in the interim, so that the prescribed standards for electricity have lost a good deal of their value. I shall return to this subject again when I come to the administrative aspects.

The question of a ' prescribed ' standard also arises in connexion with *photometry*. Hitherto candle-power and the associated quantities have been maintained by frequent inter-comparisons of various electric lamps between the leading laboratories, but it is now proposed to replace this method by a prescription, that of the light of a square centimetre of freezing platinum which is to be 60 candles, instead of 58·9. It is a difficult matter to achieve this with high accuracy, and it may prove that disagreements will arise, but the standard is anyhow not one of very high accuracy, and so it may be sufficiently good. In any case if the temperature of the platinum could be told with complete accuracy (which is hardly yet the case) it would be possible to apply Planck's formula to make an absolute definition in terms of energy flux of a black body at the correct temperature.

Photometry does, however, raise another important question. Electric lamps operate at much higher temperatures than that of platinum, and consequently the spectral distribution is quite different. This introduces questions of ' colour temperature,' and matters arise in connexion with the physiological qualities of the average human eye. There are conventions which have been adopted about this, which are certainly roughly right, but perhaps they might be bettered. I believe it is even possible that vision is seasonal, to some extent depending on the various vitamins yielded by the seasonal crops.

I have included *acoustics* in the table for completeness. It is evidently not a very precise measure yet, and whether a higher accuracy would be useful I am inclined to doubt. Here also physiological questions arise in connexion with the sensitivity of the ear for notes of different pitch.

Last we may consider *temperature*. Here we have the principles of thermodynamics to guide us, and the difficulty is mainly in making practical methods out of its abstract principles. I am not going into this subject, which takes different shapes in the various ranges. Broadly speaking the absolute thermodynamic scale is known to within 0·01° at room temperatures, to 1° at 1,000° and to 6° at 2,000°, but for details I may refer to Mr Hall's Royal Society paper on the subject.

Another aspect of the question is raised by a most interesting suggestion that was made a few years ago. Thermodynamics always determines ratios of temperature, and therefore there must be a conventional element in the scale, but we do in fact have two conventions, the freezing and boiling points of water. The boiling point, depending as it does on a very accurate absolute measurement of pressure, is the main limitation in our accuracy and the most troublesome thing to reproduce. Why should we do so at all? The proposal was therefore to adopt the best ascertained value of the freezing point on the absolute scale, and fix its numerical value at whatever that is. The only effect of a revaluation would be the trivial matter of adopting a slightly different standard pressure for boiling water. There is as a matter of fact still some difference of opinion as to whether

the number is 273·15 or ·16, and it is probably best to wait until that is cleared up before making such a change. Theoretically it is a very desirable one, but it would have little practical advantage in helping the thermometrist, because it is customary in making a precise platinum thermometer to calibrate its resistance at the freezing and boiling points of water and the boiling point of sulphur, and this process would presumably continue. Reviewing the general situation of thermometry, it would appear that there is still room for much work in the subject.

Turning to *calorimetry* a similar proposal for change of units has recently been made and with much greater force. In all modern work heat is measured by the input of so much electric energy, and the answer is given in calories by the accepted factor for the mechanical equivalent of heat. The proposal is to define the calorie as so much energy, and thus to free the subject from the wholly irrelevant question of the specific heat of water. The argument for doing so is conclusive in any case, but is reinforced by the highly anomalous and rather rapidly variable specific heat of water—three times as large as normal atomic heats. This proposal is coming forward at the next International Conference, and it is expected that it will be adopted.

I have briefly reviewed the scientific side of the standards, indicating the accuracies attained and what work is called for. As a purely personal opinion it seems to me that it is difficult work and intensely interesting to aim at precisions of 1 in a million, but I cannot feel that it is work that should be lightly undertaken by any laboratory that is not equipped for it and officially charged with the obligation. In any country where there is a shortage of scientists it is probable that greater advantage will be gained in other directions for the same degree of effort, and that it will be wiser to limit the work on standards—essential in every country—rather to secondary standards. In saying this I fear it may appear as if I was speaking as a monopolist anxious to warn others off the field. This is not so—I would warmly welcome any competition that should come, since it is competition that leads to improvement. If anyone should feel impelled to enter this field we shall do all we can to help, and I am only insisting that before embarking on such a course he should consider well what other fields he is neglecting.

I now turn to administrative matters that arise in maintaining the standards. These involve two different subjects, the international and the legal. The real scientific control is through the Conference on Weights and Measures which meets in Paris every six years, together with its committees. It is composed of representatives of countries which contribute in various proportions to the upkeep of the central laboratory at Sevres. In the British Empire the contributing countries are Great Britain, Canada and Eire. Its interests are of course in the metric system, and it would, for example, be this body which would make the decision to replace the standard metre by a wave-length standard if that should be done. It has at present on its programme a similar proposal in connexion with electricity. If the war had not come, in 1940 the electric standards were to have been changed from the International Units of 1908 to the Absolute Units, and it is now proposed—though not yet formally agreed—

to make this reform. All reforms are inconvenient and the proposal has been criticized, largely on the ground that the highest class of resistors will have to be re-certified—quite a serious business—though the effect on actual industrial practice will be otherwise negligible.

I would like to turn back for a moment to the scientific side, and consider the question, because it seems to me to involve an interesting matter perhaps not so much in electrical theory as in our psychology. There seem to be two schools of thought about the respective natures of magnetic field strength and magnetic induction, H and B, those who think of them as essentially the same and those who regard them as essentially different. I do not think the difference involves any confusion about facts excepting that our habits of thought do make us attach different importance to different things. I belong to the school that thinks H and B the same thing, whereas many of our staff regard them as different. They therefore say that there is no need to make the change ; all that is necessary is to accept that the permeability of free space is 1·0005 or whatever it may be with the existing standards, and this is no more than accepting that a millilitre is not a cubic centimetre. Notice, however, that this is a misuse of the word permeability, since one would arrive through it at diamagnetics with permeability greater than 1. To me the argument does not appeal, because to me (basing my ideas on the fields inside shaped cavities in the material, in the manner described by Kelvin) the permeability of free space *is* unity, and there is no more to be said. You will have seen a trace of our argument in the table, where the electric quantities were given dimensions in M, L, T without a special electrical dimension added. It seemed to me an improper proceeding in a laboratory concerned with metrology, to admit the existence of a physical quantity when there is not only no way of measuring it, but where a consistent and almost identical theory could be constructed with any completely arbitrary value for it. After this digression you will understand that I personally welcome warmly the proposal to change over to the absolute units. If it is done now it will only affect people who have a real understanding of the subject ; if delayed it might involve those who would be confused by its implications.

Returning from this digression, the International Committee is clearly the right body, and is well qualified to make reasonable decisions about units and standards ; but it has of course no legal force in any country, and there have consequently been difficulties in carrying out all its advice. I cannot speak about other countries in this connexion, but I find it hard to believe that any of them have a more embarrassing legal situation than we have. For example, our standard of length is the Imperial Standard Yard, which by Act of Parliament is to be measured under certain prescribed conditions of support and temperature. There have since been invented better methods of support ; do we break the law if we use them ? The temperature is to be '62° of Fahrenheit's scale.' We do not know what thermometers were used originally, but they were almost certainly of inferior glass and there was no cognizance of the absolute scale, and it is only an accident therefore if we are not now measuring the bar at a different temperature from the original one and giving it a perceptibly different length in consequence. There are opposite troubles too, where there is no legal standard at all, or still more embarrassing, as in the case of the British

thermal unit, where there is reference to the unit in legislation but no definition of it, while there are in fact three equal authoritative slightly discrepant values that might be taken.

We can manage fairly well when there is too little legislation, but when there is too much we get into trouble, and there is one very serious trouble that might easily become quite important in the not very distant future. This is the fact that the British and American inches are perceptibly different in length. The history of it is this. The British yard was set up again in 1856 after the destruction of the old standards. In America its relationship to the metre was quoted by an Act of Congress in 1886 to be 1 metre $= 39{\cdot}37$ inches, which was quite good enough for the accuracy then attainable. But in 1893 an Order of the U.S. Treasury, which is still in force, accepted this value as legally defining the American yard in terms of the metre. We on the other hand are tied by statute to our yard, and in the interim the relative length has changed (and also probably it has been more accurately measured) so that we now differ from the Americans by about four parts in a million. It is not of course certain which of the standards has changed most, but it is suspected to be the yard, because of its earlier and apparently slightly inferior design. Now it happens that the relationship can be more conveniently represented by its reciprocal in that the inch is very nearly 25·4 mm. Ours is less by about 2 parts in a million than this and the American about the same amount greater. The difference is quite unimportant in manufacture, though gauges of the very best quality would show it. I have discussed the subject with the Director of the Bureau of Standards, and he could arrange to adopt the exact definition 25·4 without great trouble. We cannot do so without breaking an Act of Parliament. The same history, though to a less degree, applies to the standards of mass, but here fate has not been so kind in that the ratio does not happen to fall near any simple number.

I regard this difference in our standards as meriting correction rather urgently, and I have explored the possibility of getting an amending Act to correct it, together with other faults in our system, but there has not been and is for long unlikely to be parliamentary time available for what is after all not a matter of great direct importance to the community. The form I proposed, which had the broad approval of several authorities I consulted, is I am sure the only satisfactory method of meeting present difficulties and also unforeseen future difficulties. It is the setting up of a permanent Commission of the Standards, with powers to revise any defects in the system as they appear, without having recourse to Parliament every time. It seems unlikely that we can get anything in the immediate future going on these lines, and we shall have to make do as best we can without, but I would strongly suggest that this is the general form that legislation ought to take, since it is the only way of expressing the fact that the conditions of measurement are so difficult that it is really not possible to make a purely objective standard, without attaching a lot of conditions to the method of measurement, conditions which could not and certainly should not be embodied in a statute.

I now turn to the question of the rival merits of the British and metric systems. As scientists, I think we may assume that we all agree that the

metric system, including centigrade thermometry, is the only reasonable one to use. Proposals have from time to time been made to decimalize the British system, but to do so would mean an upset not far from that of going over to the metric, and if we are to have this upset we might as well go the whole way and get the benefit. I have had many arguments, especially with engineers, who maintain the great convenience of 12 inches in a foot, and are not deterred by the implication of 1,760 yards in a mile. There is, however, one aspect which must be kept in mind and that is the convenience in the absolute magnitude of some of the most important units. Thus we may judge that the kilogramme is a bit too large from the fact that in shopping in Europe the pound, as a half-kilogramme, still survives. Similarly for many purposes the metre is inconveniently large and the centimetre too small ; at least it is hard to see any other reason why the foot survives, especially in such fantastical absurdities that we commit in measuring heights in feet and horizontal distances in yards. But this argument defending our units must not be given too much weight because the scales of things are so varied that what is ordinary size for one becomes enormous for another. For example, if we press for the pound and the foot as our convenient units then a Young's modulus will become an extraordinarily large number of pounds per square foot, and incidentally will give trouble to those unfamiliar with the calculus in that the stress would usually not be constant over a square foot. Such an argument as this indicates that we have got to be ready to scale things up or down, and to do so by factors of 10, using affixes of kilo- and micro-, etc., is surely a quite admirably convenient way of doing it.

Many of us would like to see the radical reform made of adopting the metric system, but we have to recognize that to do so would encounter enormous opposition, partly sentimental but also economic, in that it would entail providing new weights for the scales in every shop in the country, and new drawings for the great majority of engineering products. I cannot feel that there is any serious chance of this coming about, and as the practice of politics consists in having a sense of the attainable I think we must look for something more modest.

As a matter of present policy we have the chance of making the English-speaking world the centre of learning to the smaller nations in a way that Germany used to be. This position of Germany was partly due to the very thorough way in which their authorities studied and produced books on all branches of learning, but if say a Norwegian had wished to attach himself to us instead of Germany in this manner he would have been faced at the outset with our quite intolerable jumble of units which would have discouraged him. Can we do anything to ease this situation ?

We have first of all to recognize one point. Apart from having to know a lot of curious multiplication tables, as long as one sticks to a single system of units, and perhaps remembers one or two numerical constants (like g, or the weight of a cubic foot of water), there is not much in it which system one uses. What is really difficult is to keep *two* sets of units in mind, because there is always the confusion that when one unit is larger than the other, the numerical value of a quantity in the first is smaller, and it involves care to get it the right way round. We can all see this difficulty in cases where it is unavoidable, in particular in the electromagnetic and electro-

static units, but in most other systems a single set of units is sufficient, and it is simply making unnecessary difficulty to have two. We cannot expect that foreigners will learn their English multiplication tables, when they already talk a universal language, and therefore we have got ourselves to face this difficulty, and we must consider how we are to go about it.

Some sciences are happily free from the duality. In electricity our fathers very wisely fought a strong battle, against much opposition, and established the metric system. I believe it is not unknown for an electrical engineer sometimes to speak of so many magnetic 'lines to the square inch,' but for the most part they are reasonably consistent. There is in electricity, however, another question arising, the change over from one set of metric units to another. There is first the theorist's taste for the Heaviside units, which suppress a lot of 4π's, but pay for it by introducing sometimes $\sqrt{4\pi}$. On this I happen to be a conservative, for I notice that the most strenuous advocate of it will cheerfully continue to dot his formulae with the 2π's that come from using cyclic frequency instead of radian frequency. The fact is that nature does insist on the existence of π, and as we have to accept it so often, we may as well, as I think, accept one more—to which I am used. Then there is the proposed metre-kilogramme-second system, which happens to make ampere and volt natural units instead of being powers of tens of units. It pays for this advantage by a little complication in connexion with magnetism, and also by the slight awkwardness that one measures a flux as so much per square metre, when it is hardly ever constant over more than a few centimetres. It seems to me that the proposal is to be taken seriously, but hardly that it is very important. In fact I am personally quite indifferent about it.

In optics too focal lengths are measured in metres, and spectral wavelengths in Angströms, but there is a tendency to refer to gratings as having so many lines to the inch, which seems to make quite unnecessarily difficult the calculation of where the spectrum of a given spectral line will fall. In photometry the candle-power is international, but we spoil it by the habit of speaking of foot-candles. All these matters could be put right, as it would seem, without too much trouble or upset.

In meteorology we are in a good position, for it was I believe British meteorologists who introduced the proper pressure unit in the form of the millibar, and they also introduced the absolute temperature scale with the trivial but convenient inaccuracy of taking the freezing point of water at 273° exactly.

It is in the older science of mechanics that the trouble comes most strongly. It is really two troubles, one not connected with the metric system at all, but lying in the way in which the engineer writes his equations with what appears to the physicist to be the g's always put in the wrong places. It was Lord Rayleigh who said, 'the engineer, who claims to be a practical man, never puts in the value of gravity when he is dealing with a purely gravitational problem, and always puts it in when his problem has nothing whatever to do with gravity.' Here again we come across the point that what is troublesome is to have to deal with two systems, and that a single system however ill-chosen is not too bad. As long as engineers were mainly concerned with statics their choice was not unreasonable, but now, when accelerations, both of mechanisms

and of aircraft, are constantly present it is lop-sided to use this system, and indeed it has largely been dropped by the use of the 'poundal' or alternatively of the 'slug'—but is a slug 32 lb or 1/32 lb? I was recently urging that in aerodynamics it would be a not very difficult change, of great practical convenience, to go over to the international system, but most of those present claimed that they were so used to the old system that it would be a formidable task to alter it. They claimed that anyhow nearly all their work is non-dimensional so that there was no need for the change, and they would not consider the reply that the change should then be so easy that it was not worth protesting against it. I have no experience of work in aerodynamics, but I cannot think it really convenient to have to work out a Reynolds' number from a span measured in feet, a velocity in miles per hour and a kinematic viscosity in square centimetres per second. In this discussion there was only one supporter of my proposal, a recently appointed professor, who said that his trouble was the opposite—that the boys came from school knowing the proper mechanical system, and the first thing he had to do was to teach them the system of the engineer; as I should say his first need was to corrupt the youth. This matter is one for domestic consideration, and it must be noted with regret that users of the metric system are also open to the same charges.

Coming now to the question of the metric system in mechanics there can be no doubt whatever that there is enormous opposition to it on the part of engineers. I think this is mostly but unconsciously on the ground I have mentioned, that what is troublesome is to have to use two systems, and not really to any objection to it in itself. There is the fear that it would take simply years to get used to it, but I believe this fear is unfounded and that it would be a matter of a few weeks; I judge this from having myself sometimes in other matters changed over from one convention to another, and found how quickly the habit is acquired. However that may be, there can be no escape for our engineers, if they are going as they wish to open up foreign markets for their products, and it is an insufficient defence that the chief industrial producing countries work on British standards, because no one who has been brought up in the metric system would tolerate going over to ours.

How then are we to proceed? In a very modest way we have started at the National Physical Laboratory an experiment to see what can be done in the way of giving data so that both parties can follow a paper without trouble. The first idea that one might start with is that wherever a quantity is given in feet or inches, one should put the metric equivalent in parenthesis after it. This can often be done, but it does not solve the problem in many cases, and other solutions must be found. For example, if a long table of some quantity is given in pounds per square inch, is one to write a second parallel column in dynes per square centimetre? This seems too elaborate, but the point can be met by printing a single conversion factor at the foot of the table. So too in a diagram, if the ordinate of a curve is marked in feet on the left, it may be possible to graduate in metres on the right as well. Another alternative may be to provide somewhere in a paper a conversion chart in which one side of a line is graduated in British units and the other in metric; it would probably best be done on

a logarithmic scale. One of the troubles about this business is in the conversion of rough magnitudes, for example—'the mirror was about two feet in diameter,' or 'the tolerance was one thousandth of an inch.' In such cases it calls for some discretion to be neither too precise nor too inexact in the translation.

We have not gone very far with this business yet, and I expect experience will suggest other ways of doing it. It must be confessed that they all involve trouble that *we* shall have to take for the benefit primarily of the foreigner. But I do not believe that in the long run it will be anything but an immense advantage to ourselves for through it we shall acquire a better contact with the other half of the world.

PHYSICAL STANDARDS AND UNITS OF MEASUREMENT IN INDIA

By Professor P. C. Mahalanobis, F.R.S. and Professor M. R. Siddiqui

The adoption of a uniform system of currency received early attention by the British Government in India. The diversity of weights and measures prevalent in the different provinces or even in the different districts or villages of the same province was and still continues to be a difficult problem. In Madras an attempt was made in 1801 to introduce a revised system of weights and measures which, however, was apparently not carried out in practice. In the Bombay Regulation XIII of 1827 it had been laid down that standard weights and measures should be maintained by magistrates, but this also did not make much progress.

An Act was passed by the Government of India in May 1833 which fixed the weight of the rupee Furrackabad at 180 grains English weight, and in 1835 the *sicca* rupee of 192 grains was abolished. Since then the rupee coin in India has been of the standard weight of 180 grains throughout British India.

In 1839 the Madras Government appointed a committee for the standardization of weights and measures and this committee in its report in February 1841 recommended in favour of a decimal scale but this was not approved by the Government of India. In 1847 the Madras Government issued a proclamation introducing certain new standards, but this also remained a dead letter.

In November 1854 the Government of India resolved that the standard railway weight should be the Indian maund of 40 seers = 82-2/7 lb.

Other proposals for standardization were made from time to time but no further action was taken until June 1864 when the Government of India requested each province to appoint a separate committee to consider the subject of weights and measures. Several such committees were set up and a great deal of detailed inquiries were made in the different provinces. The Bengal Government recommended the adoption of the metric system, and the Bombay Government a decimal system based on the English pound and foot.

In January 1867 the Government of India appointed a committee consisting of members from different provinces; and in 1868 this committee recommended the adoption of—

> 'the English standard of weights and measures and length, on the ground that such weights and measures would best afford facilities of English trade. This report pointed out that the English system had to some extent been introduced in India and was more likely to meet approval from English officials who would therefore be more willing to further its introduction.' (Report, 1914, p. 17.)

Three members of the committee recorded a strong minute of dissent stating that the English standard had not been introduced into India to any considerable extent, and that the English system must give way to the metric system before long.

The Government of India, in forwarding the report to the Secretary of State for India, proposed that the metric system with decimal subdivisions should be adopted as far as possible, and the Indian Weights and Measures Act XI was passed in March 1870, but the Secretary of State for India refused to sanction the bill. A new Act XXXI of 1871, in conformity with the suggestions of the Secretary of State for India, was passed, but in March 1872 the Secretary of State for India ordered all steps for introducing the Act to be suspended. This was due to a division of opinion among the railways (several of which at that time were private companies) some being in favour and some opposed to the introduction of the new bill.

The difficulty experienced in obtaining correct agricultural, railway and trade statistics owing to the diversity of weights throughout India reopened the question of weights; and in October 1875 the Government of India decided that the Indian maund of 40 seers (each seer = 80 tolas) should be the standard in use on Guaranteed and State Railways.

By Act II of 1889 the Imperial standard yard (subdivided into feet and inches) was made standard, and has been since then the only legal standard measure of length in British India. Nothing, however, was specified regarding square or cubic measures.

Another inquiry initiated by the Government of India in 1889 indicated the very great diversity in weights and measures in actual use, especially in regard to measures of capacity which varied not only from district to district but even from village to village.

In January 1901, the Secretary of State for India forwarded to the Government of India copies of a paper presented to Parliament regarding the adoption of the metric system of weights and measures in European countries. The Government of India were, however, averse to taking any action and preferred to wait before proposing a change in the Indian practice until the United Kingdom had decided to adopt the decimal system.

Between 1902 and 1913 various proposals were made by public bodies and different provincial governments, and some action was also taken in Bombay and Madras. In 1913 a fresh committee was appointed by the Government of India which submitted a comprehensive report in 1914 giving a great deal of detailed information relating to weights and measures in actual use in different parts in India. The committee made definite recommendation for the introduction of standard weights, measures of length and also of cubic content, including proposals about the system of inspection, maintenance of necessary standards, penalties, etc. The report was signed by the three members of the committee subject to a strong note of dissent by Mr A. Y. G. Campbell, who strongly advocated the introduction of the metric system. Since 1914 there has been a great deal of discussion of the subject but little tangible has been accomplished.

Bill for decimal currency. Very recently, on 4 February 1946, a bill was introduced by the Government of India in the Legislative Assembly to

convert the currency to the decimal system of coinage retaining the rupee as a standard unit and dividing it into 100 cents. This bill has been circulated for eliciting public opinion.

Public opinion. The Indian Science Congress Association at its Bombay session in 1934 had passed a resolution recommending the introduction of the metric system. Shortly before the outbreak of hostilities, the Indian National Congress had appointed a National Planning Committee with Pandit Jawaharlal Nehru as Chairman. In April 1940 in the interim report of the Manufacturing Sub-committee of the National Planning Committee the following recommendation was made :—

> ' Standardization of weights and measures on all-India basis should be carried out at any early date so that a uniform system of weights and measures is applicable to the whole country. For this purpose an institution similar to the British Standard Institute should be established at a central place. If other conditions permit, the metric system should be adopted for this purpose.'

The Indian Decimal Society was started in 1944, and has been since then actively striving to educate public opinion in this matter. The Indian Science Congress Association at the recent Bangalore session passed the following resolution unanimously :—

> ' Resolved that the Indian Science Congress Association at its annual session assembled in Bangalore on 3 January 1946 endorses the recommendation of its different committees and places on record its strong support of the proposal for the decimalization of currency, weights and measures in India simultaneously if possible.'

The matter was further considered at a meeting of the Executive Committee of the Indian Science Congress Association held on 8 March 1946 and presided over by Pandit Jawaharlal Nehru, President-elect of the Association, and the following resolution was passed unanimously :—

> ' Resolved that the Science Congress notes with satisfaction that a Bill for the decimalization of Indian Currency has been introduced in the Legislative Assembly. The Science Congress is, however, of opinion that decimalization of currency alone is not enough, and considers the decimalization of weights and measures on the basis of the metric system to be equally urgent.'

Present position. The need of uniform standards of weights and measures is now widely recognized throughout the country, and scientific opinion is unanimously in favour of the introduction of the metric system. A considerable volume of public opinion also appears to be in support. The Weights and Measures Committee in its report in 1868 had advocated the English system as this was considered to be of advantage in developing trade between the U.K. and India. This argument is not likely to find favour with Indian opinion in future. In fact, one important consideration in India would certainly be the advantages of the metric system in developing international trade. As far as one can judge from the trend of public opinion, it does not seem unlikely that the metric system would be adopted in India before long.

In the future programme of action, emphasis is, however, likely to be laid on the need of simultaneous introduction of the metric system and decimal coinage. In India the standard maund consists of 40 seers; and a seer consists of 80 tolas (the weight of a rupee coin being a tola = 180 grains); a seer is also subdivided into quarters and sixteenths. The rupee is subdivided into 16 annas, each anna into 4 pice, and each pice into 3 pies, for purposes of calculation while coins of the value of 1/2, 1/4, 1/8, 1/16, 1/32, 1/64 and 1/192 of a rupee are in current use. There thus exists a fairly close link between the standard weight and its multiples and sub-multiples on one hand and the standard rupee and its sub-divisions which makes oral calculations often very simple and quick. This, quite rightly, is pointed out as an advantage of the existing system especially in country in which most of the people are illiterate. Simultaneous conversion to the metric system and decimal coinage would be obviously desirable.

Another point is also worth mentioning. Opinion is likely to be strongly in favour of retaining Indian names. This should not prove any serious obstacle. For example, the *dasa* from *das*, meaning ten, was actually used as one-tenth of a rupee in the time of Akbar; the name can be easily revived. Similarly, as already noted, *satamana* is a Vedic word; *sata* may perhaps be used in the place of the cent. The Indian name *gaz* (usually referred to yard) may be retained, but its length changed to the metric; seer, in the same way may be defined to be equal in weight to the kilogramme (from which it differs only very slightly). If the metric system is introduced it would be probably also desirable to link the weight and the diameter of the standard coin with the metric system in a suitable way. These are, however, details which can be best worked out by a committee in India.

Physical standards

The Government of India have already sanctioned a scheme for the establishment of a National Physical Laboratory and necessary arrangements are being made for this purpose. The maintenance of standards of length, mass, time, area, volume, density, pressure as also of electric, radio, optical or acoustical standards would be normal functions of the new institution.

It would be desirable to arrange necessary collaboration, at the technical level, in such matters between the National Physical Laboratory in India and similar institutions in other countries of the world.

Industrial standards

India is at present extremely backward in the matter of industrial standards and specifications. A Committee on Statistics, Standards and Quality Control has been set up recently by the Board of Scientific and Industrial Research (Government of India) and has made various recommendations which are under consideration by the Government. The Committee has emphasized the need of a Statistical Institute for the advanced study and research in quality control and the application of statistical methods in industry. On the recommendation of the Committee a course of instruction on quality control is also being given in the Indian Statistical Institute for technicians.

A scheme for an Indian Standards Institution on the lines of the British Standards Institution is already before the Government of India. Such an institution is essential for the advancement of industrialization in India. In large sectors, standard specifications as well as limits of tolerance should be the same or closely co-ordinated with similar standards and specifications in other parts of the world. It is recognized, however, that owing to regional differences in climate, raw materials and even social and economic conditions, it may be necessary to set up regional standards and specifications in particular sectors suited to Indian needs. It would be desirable, however, to set up such local or sub-standards within a larger framework of international standards. The help and collaboration of appropriate institutions in other countries would be necessary. An urgent need in the first instance would be to give necessary training to the technicians who would be required to take up the above work in India.

Symbols, statistical terms and standards

Owing to the rapid increase in the application of statistical methods it has also become necessary to achieve some measure of standardization in statistical notation and presentation of results. In sample surveys, for example, names and symbols for fundamental concepts and units as also methods of classification is an urgent necessity. Conventions regarding the use of the standard error (instead of the probable error) for specifying the margin of error, and levels of significance in presenting results of tests of significance are equally desirable.

Although a good deal of uniformity has been already reached in the scientific terms and symbols used in the medium of the English language, much further standardization is still necessary. It is suggested that a Special Committee should be set up for this purpose.

There is one problem peculiar to India which must, however, be tackled within the country. Textbooks for use in schools as well as popular books on science are being and must be increasingly written in the different vernacular languages of the country. Standardization of notation, units and symbols as between the major vernaculars of India has become an urgent necessity, and must be achieved in such a way as to facilitate easy and unequivocal transition to international usage.

The question of the national language is engaging the attention of the people in India. Education up to the high school stage is already being imparted through the medium of the provincial language. University education may also be imparted in future through the medium of the national language. Therefore, the questions of terminology and symbols that confront India now, and would confront more and more in future, are characteristic to India, and would have to be solved separately.

MORNING SUBJECT (i)

DISCUSSION OF THE COLLECTION AND INTERCHANGE OF SCIENTIFIC RECORDS AND EXPERIMENTAL MATERIAL INCLUDING THE SAFEGUARDS THAT WILL HAVE TO BE TAKEN TO MINIMIZE THE RISK INVOLVED IN THE DISTRIBUTION OF PLANTS, SEEDS AND ANIMALS

Steering Group

Chairman and Recorder—Sir Edward Salisbury, Sec. R.S.

Dr S. Adler
Professor A. T. Cameron
Mr J. K. Chorley
Dr A. R. Saunders
Professor Birbal Sahni, F.R.S.
Professor F. G. Soper
Dr H. C. Trumble

Report

The discussion concerned the aim and scope of biological collections, whether of living or non-living specimens. With regard to living collections, the safeguards necessary to minimize the risks of introducing pests, diseases, or both, were considered. As to the scope of collections, it was felt that a measure of rationalization was essential, if unjustifiable overlaps were to be avoided and important gaps properly filled.

The following general principle was discussed and accepted by the Conference. One or two comprehensive and cosmopolitan collections only in each of the major groups of material should suffice for the scientific needs of the world. Apart from such collections, scientific manpower and other resources would be directed to the best advantage if national collections were comprehensive only with respect to their particular regions. The intensive representation of families or smaller groups characteristic of regions should be the aim of these collections. Similarly, specialized institutions might assist in the intensive collection of particular groups representative of their respective areas. By such localization it would be possible to maintain living collections in the environments most suited to them. Moreover, complementary collections might be made in museums or herbaria specializing in non-living material of the same affinities.

To render such rationalization effective, every effort should be made to ensure the distribution of co-types or, where this is not possible, photographs, casts, etc., among those institutions which have accepted the responsibility of intensive representation of the groups to which any newly described species may belong.

The Conference recognized that systematic exploration was needed to ensure adequate living collections. In making them, however, careful consideration should be given to the intrinsic value of specimens, whether for their own sake or as sources of genetic characters for the plant breeder. Otherwise the expenditure on maintenance, both in time and personnel, might well be out of proportion to the scientific dividend.

The interchange of material among collections involves a risk of spreading insect pests, fungal diseases and virus infections. The experience of New Zealand had shown that no system of quarantine stations or of the inspection of imported material could provide a complete insurance against such risks. Such measures, however, could be of much value in providing a delaying mechanism enabling protective and repressive measures to be devised and

developed before the extent of any fresh menace rendered its effective control impracticable.

The importance of maintaining collections of type material of the lower groups of organisms was emphasized. The difficulties of their accommodation and maintenance could be greatly reduced by the methods of rapid freezing at low temperatures and dry storage.

Recommendations

1. That having regard to the limitations of space and scientific manpower we recommend a policy of rationalization in respect to research collections for taxonomy. To this end the avowed scope and objective should be publicly stated by each institution, especially as to the particular groups for which it accepts responsibility of intensive representation.
2. That, when new species are described, replicates should, where possible, be provided for major cosmopolitan collections and for those institutions where the group concerned is intensively studied. For unique specimens, microfilms, casts, etc., should be similarly provided.
3. That increased provision be made for the training of taxonomists and that an increased number of taxonomic posts be created.
4. That better facilities be provided for the collection of living material, for its reception when collected, and its subsequent maintenance.
5. To ensure early action and continuing attention for varietal collections of economic species, for genetic and breeding purposes, one organization in the Commonwealth should be specifically entrusted with the essential central co-ordination.
6. That adequate quarantine measures should be taken respecting new introductions to ensure their supervision before release and that competent diagnosticians be available. Such quarantine measures to be supplemented by a good intelligence service.
7. That information regarding the geographical distribution of pests and diseases should be made readily available.
8. That steps be taken to preserve native breeds of livestock.
9. That increased provision be made for the collection of fossils.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr F. M. Burnet

It is a practicable matter to maintain collections of animal viruses by utilizing preservation at a temperature of —73° C. in solid carbon dioxide refrigerators. The method may have application in other fields notably for maintaining collections of protozoa.

A collection of standard virus strains will serve—

(*a*) for the provision of seed virus for vaccine production
(*b*) to maintain strains needed for production of diagnostic reagents
(*c*) as a reference collection for research workers.

In general such a collection should be associated with type culture collections of pathogenic bacteria.

Professor E. E. Cheeseman

Our experiences in Trinidad with a collection of varieties and species of *Musa* illustrate some of the principles enunciated by previous speakers.

The collection is in two parts, the edible banana varieties being propagated as clones and the wild species as seedling families. The latter, being naturally cross-pollinated, are variable and for full exploitation of their variation must in the first place be thoroughly studied as *populations*. Later, the seedling populations can usually be reduced for convenience to a very small number of clones; but if this is done too quickly there is a danger of valuable combinations of genes being thrown away.

The edible varieties must perforce be introduced as vegetative material, and the risks of introducing with them diseases not yet in the West Indies are too serious to allow direct introduction from many countries. Therefore they all go through a special quarantine house at Kew, which involves some delay but provides an invaluable safeguard. The principle of quarantining in a country where the quarantined species is of no agricultural importance may be worth noting in other cases.

The uses of our *Musa* collection are several. It can be used by the crop taxonomist for the study of established varieties and the reduction of synonymy. To be of any value in this connexion it must be maintained with the most scrupulous regard to accuracy of labelling. I believe that no mechanical method can ensure accuracy, and that it is necessary for the botanist in charge to know intimately every individual in the collection. The number has never yet become too big for that condition to obtain, but if ever it did, some method of subdivision would become necessary.

The second use is the direct employment of the fertile species as parents

for the new edible bananas, and the plant breeder's special concern is to avoid discarding useful genes or combinations of genes whilst keeping numbers within practical limits.

A third use is as material for cytogenetical investigations essential to guide the practical breeding. These can often extract extremely useful information from material quite useless for direct breeding.

Finally it is worth noting that many of the forms are kept in a parallel collection in Jamaica. The advantages are obvious, and I would urge that wherever only one main collection is possible for a genus or crop group there should always be some arrangement for duplication at least of parts of it on subsidiary stations. There will always be some losses, which can be more easily and cheaply made good from a duplicate or reserve collection than by re-collection at the original source.

Mr J. K. Chorley

My part in this morning's discussion is to describe, in brief outline, the working of the international project which is already in being and which has functioned successfully in East and Central Africa for several years. This is a scheme for the suppression and control of the Red Locust and for intensive research into its biology and ecology.

For those who are not familiar with the problems, I had better preface my remarks with a short account of the life cycle of this insect.

The permanent home, i.e. permanent breeding grounds of this locust are known—with a fair amount of accuracy—to be restricted to certain grassland areas in the vicinity of Lake Rukwa in Southern Tanganyika and in the Lake Mweru area in the Belgian Congo. Other permanent breeding grounds may occur but the ones mentioned are definitely incriminated.

Under certain favourable conditions this locust—which exists in its permanent home as a solitary grasshopper—assumes a gregarious phase. It increases enormously in numbers and migrates over vast areas of Central and East Africa causing tremendous loss to the cultivator and pastoralist. Actual famine conditions frequently result in the native areas when their crops are destroyed.

This swarm phase may last for several years—during which it breeds normally in all the territories overrun by it in its migrations—so long as climatic conditions are suitable. Eventually the migratory phase dies down and the pest disappears from the areas it has covered during its migrations. Incipient swarms may build up very rapidly in the permanent breeding grounds and over a period of years the migrating swarms may reach as far north as Uganda and as far south as Natal.

The last great swarm period of this locust commenced about 1928 and began to die down about 1936 at least as far as Southern Rhodesia is concerned. The cost of crop protection is almost prohibitive and at the best can only be a palliative. I have not got exact figures but I believe in some years the Union Government has spent over £250,000 annually on anti-locust control against the Brown Locust.

The anti-locust control in London—supported by most of the East and Central African Governments—carried out research work in East Africa for a number of years during the height of the last swarm cycle. At the

last anti-locust conference held in Bruxelles in (if I remember rightly) 1936, the British Government put forward a scheme for the control of this locust in its permanent breeding grounds and for intensified research into its biology and ecology. The scheme was accepted by most of the territories concerned, but the outbreak of war in 1939 made it very difficult to get things started.

Eventually—possibly as a war measure for the preservation of food crops—a start was made about 1941. Like most things it commenced in a fairly small way beginning with two senior, experienced locust officers—one a Belgian and one British with a field recording staff of trained natives with headquarters at Abercorn in Northern Rhodesia. Things went reasonably smoothly until about two seasons ago when incipient swarm formations began to build up in the areas under observation and these last year assumed alarming proportions. An emergency conference was called together during August last when an *additional* amount of £35,000 was provided by the contributing governments to intensify the campaign. The Government of the Union of South Africa—which is not a contributory state—gave £10,000 and the services of two entomologists and additional staff were provided by other governments.

The cost of this work has increased each year. During the present year the budget is £15,000 divided proportionally according to an agreed formula amongst the contributing states. The individual amounts contributed by each state for the normal budget this year is as follows :

	£	per cent
Kenya	1,800	
Uganda	1,050	
Tanganyika	2,400	50
Northern Rhodesia . . .	1,350	
Nyasaland	450	
Southern Rhodesia . . .	2,250	17
Belgian Congo and Ruanda Urundi	4,950	33

The British Colonies are paying 50 per cent of the cost, Southern Rhodesia 17 per cent and the Belgians 33 per cent. In addition a very large sum in capital expenditure is being provided under the Colonial Development and Welfare Act.

The anti-locust research centre in London acts in an advisory capacity and the Government of Northern Rhodesia as accountants, etc.

The scheme as described is a concrete example of complete collaboration in regional research and control of an insect pest which does not recognize international boundaries. It works fairly successfully and we hope, as time goes on, will become even more international in character by the inclusion of the Union of South Africa and Portuguese East Africa. There is no doubt that given the necessary goodwill similar research schemes—I leave out the question of control—could be developed for work on the various problems mentioned by previous speakers and similar financial arrangements could be made to cover the cost.

There is one other scheme perhaps worth mentioning. All the Southern African states including the Belgian Congo have agreed to enact similar legislation or make similar regulations for the control and prevention of

the introduction of plant pests and diseases. It should be a fairly easy matter to agree on the plans for regional research into many of these pests.

Finally in closing I welcome the proposals put forward this morning for regional research and investigation in Africa, but in so far as fundamental research into the problems of tsetse and trypanosomiases it should be clearly understood that fundamental research must not be permitted to interfere with the local application of applied science. There is a vast store of knowledge already available which can produce valuable immediate results if practical methods are put in hand now without waiting for the results of more fundamental research. There is only a limited amount of money to go round.

Dr J. C. Hopkins

1. With regard to Professor Brook's suggestion for a central organization to control at source the spread of plant diseases, the Imperial Mycological Institute has been issuing for some years maps showing the distribution of the more serious plant pathogens. This might be used as a nucleus for a larger organization to serve the purpose outlined by Professor Brooks.

2. There is a tendency among plant pathologists to regard imported seed as relatively innocuous. Experience in Southern Rhodesia suggests that seed may be a very fertile source of disease importation. During the war some vegetable seed from America found its way to the Plant Pathology Department simply because it had a poor germinating capacity.

It was grown under observation and many diseases unknown or rare in Salisbury developed. One instance was what appeared by the symptoms to be the virus of sugar beet curly top caused by a dangerous virus not previously known in Africa. As far as can be ascertained all the seed was destroyed but some may have been sown and the disease may yet appear in epiphytotic conditions.

3. In order to assist plant breeders and geneticists, it is suggested that more use be made of pollen, suitably preserved for transport over long distances. This would in some degree obviate the necessity of importing both plants and seeds with the added advantage that pollen is not known to transmit viruses.

Dr S. L. Hora

In referring to taxonomic work, Dr Hora stated that with the rapid growth of more attractive sciences of physiology and experimental biology in the Universities, taxonomy became less and less popular and unless the status of taxonomy was raised it was not likely to attract better type of workers. He, therefore, suggested that taxonomy should be studied in combination with ecology, a very fascinating and fruitful line of research.

Mr Afzal Husain

Enough has been said regarding the necessity of maintaining collections of living plant material and cultures of micro-organisms, and their interchange between workers in different countries. Indeed there will be a constant demand for the introduction of new plants and better varieties of existing plants, from one country to another, for increased production or to

obtain material of desired qualities. There will be need for interchange of varieties for hybridization and other experimental purposes. It is evident that collections of living plants, both wild and domesticated, and their varieties are essential for the development and progress of scientific plant husbandry. I, therefore, fully support what has been said already, and I wish to add that there is need for similar collections of living animals. So far nothing has been said on this aspect of the question. Among the smaller animals we have the honey-bee, of which several species and races occur in different parts of the world. These may be introduced from one region to another to replace inefficient indigenous bees or for hybridization to evolve better races. Similarly there are several species of wild and domesticated silkworms and many races of the well known mulberry silkworm. We have numerous races and varieties of fowls, ducks, pigeons and rabbits. Again various wild game birds and valuable fur animals may with advantages be introduced from one country to another. The same applies to fish. Brown trout and Rainbow trout have been introduced into certain streams in North India with great success and European trout and tench have been introduced in South India. As fisheries develop there may be demand for further introductions. Coming to larger animals there are goats, sheep, pigs, cattle, horses, camels, etc., of which numerous varieties have been evolved in different parts of the world, and many have been introduced from one region to another for the purpose of improving such qualities as milk yield, flesh, capacity for work, wool, and so on. Just as in the case of plants, introduction of animals from one country to another for breeding and genetic studies is necessary. The arguments which apply to the maintenance of the collections of plants and their varieties apply equally to animals. It should be possible to maintain such collections at different centres so that the wild species are preserved, breeds of domesticated animals are not lost and the genetic reservoir of every species is fully maintained for future work.

There are risks involved in interchange of such material, but this question is being dealt with under a separate head. Development of artificial insemination may reduce the necessity of the transfer of males from one country to another as it may be possible to transfer sperms by air.

Mr Afzal Husain

The exchange of living plant and animal material between different countries has been responsible for rapid progress in agricultural improvement and fruit growing as well as in animal-husbandry. In India we have successfully introduced from other countries several of our staple crops and varieties of fruits. We have also introduced breeds of poultry, sheep, cattle, horses and some fish, to mention but a few. We have been importing for many years silkworm eggs from France, Italy and Japan. Some attempts have been made to import honey-bees. Such introductions shall have to be continued in the future. We have discussed in this Conference the advantages of chains of breeding stations and exchange of material between investigators. We have discussed the possibilities of co-operative expeditions for collecting plant and animal material on world wide scale.

It is necessary, therefore, that if we contemplate exchange of living

plant and animal material on an extensive scale, we must safeguard against spread of pests, diseases and weeds. Dr Cunningham tells us that more than 98 per cent of the 800 pests and diseases of agricultural crops in New Zealand are of foreign origin. In India several of our most serious pests have come from abroad, such as the Potato Tuber Moth, San Jose Scale, Codling Moth, Wolly Aphis. India has also repaid the compliment by sending out some serious pests. Of our most serious weeds Larntaria and water hyacinth are exotic.

The dangers lie in several directions. Pests and diseases may be introduced on commodities of animal and plant origin—food grains, fruits, timber, skins, etc. These can be subjected to a more drastic treatment than living plants and animals. On living plants and animals new diseases and pest have an easy access to a country, and sometimes new plants and animals have themselves become serious scourges in their new homes.

It is necessary that we insure that all living material is suitably examined and declared free from all diseases and pests before release for distribution from the country of origin. Similarly it should be examined and properly treated at the port of entry before it is allowed into a country. Further, we must possess full knowledge of the pests and diseases occurring in the different countries to keep a careful watch. We cannot, however, ignore the possibility of a harmless germ or plant or animal developing into a serious malady in its new home. All this necessitates a very effective and adequate quarantine service. India has recently established such a service. It is necessary that such services be established in all countries, or at least on regional basis.

Professor A. E. Muskett

There is a real need for improved methods in the collection and distribution of living cultures of micro-organisms, etc., and there is little doubt that the demand for a more effective service of this kind will steadily increase.

At present there are two main sources from which such cultures may be obtained : (*a*) from a type collection such as those of the Lister Institute and at Baarn or (*b*) from a centre of investigation where work with the organism required has been in progress.

In devising an improved method of collection and distribution it appears that the main decision to be made is whether large national or international collections should be built up from which stocks could be drawn or whether a more decentralized system would be desirable.

The building up of very large collections would have the following disadvantages :

(*a*) It would require an almost new and elaborate organization and would involve very considerable fresh expenditure.

(*b*) In the course of time such a collection could become unwieldy. The monotony of the routine and the impersonal nature of the work might introduce a measure of carelessness in sub-culturing and labelling. The sense of personal responsibility for the correctness of a particular culture would tend to be lost.

(*c*) Serious damage to or the destruction of such a centre would cause an almost irreparable loss.

An intermediate system, however, where large stocks would not necessarily be centralized and where the central organization would act more as a clearing house than a stock centre, would eliminate the disadvantages of a national or international collection and, at the same time, retain its advantages. Such a scheme would operate as follows :

(*a*) Provincial, regional or smaller national centres would undertake the work of maintaining collections of micro-organisms, etc., of special interest in their respective areas. Equipment is already normally available for this work and little additional expense would be involved. Such collections would not be exhaustive but would be representative of the special work or interest of the area. If required, guidance as to what specimens such a collection should contain would be given by the central organization. The result of this policy would be to retain greater personal responsibility for the authenticity of cultures and more detailed information regarding methods of culturing, etc., would be available than would be likely in the case of huge collections subject to mechanized handling. The erratic behaviour of cultures of many micro-organisms frequently calls for the more intensive and specialized knowledge which should be available under such a scheme.

(*b*) Information as to available cultures would be provided at regular intervals to the central organization where it would be collected and distributed in catalogue form.

(*c*) The central organization would maintain stocks of cultures only where local facilities for this service were not available and the loss of valuable types likely to ensue. Further than this it would not attempt to build up a collection. Alternatively, such cultures would be passed on to appropriate centres for propagation and the central organization would be relieved completely of this side of the work.

(*d*) Whether or not the request for cultures would be made through the central organization or direct to the centre responsible for their maintenance, is a point which would have to be decided. *The estriction of inquiry to the central organization would assist in the prevention of the indiscriminate distribution of cultures where such distribution might be regarded as undesirable.*

(*e*) The cost of the organization would be partially or completely defrayed by making a charge for cultures.

In so far as the British Commonwealth is concerned the natural centres to serve as headquarters for this work would appear to be the respective Imperial Bureaux or Institutes which have been set up to deal with the biological sciences. These organizations already possess certain taxonomical facilities and the wide knowledge which would prove invaluable contributions to the successful working of the scheme.

Such a scheme as that outlined would have the advantage of being applicable almost immediately without the necessity of long term planning and the expenditure of a very large sum of money. It would be evolved gradually and could readily be improved in the light of practical experience as it developed.

A commencement could be made in the United Kingdom from which it could readily and rapidly be extended to the Commonwealth. This might ultimately form the basis for an international organization.

The setting up of a small working committee would seem to offer the best means for commencing operations.

Finally, I believe I can say that Northern Ireland would willingly co-operate in making whatever contribution it could towards the successful working of such a scheme.

Dr R. Newton

The preservation at some central point of type cultures of organisms useful in fermentation processes and industries is an important aspect of this general question. During the war we in Canada made a wide search for organisms effective in the production of cutylene glycol (for rubber synthesis) from wheat. Among organisms active in this fermentation some species, even of the same genus, were much more efficient than others. The best ones should be preserved and made permenantly available. This is merely an example of the need for a service which is likely to become more important as fermentation industries based on agricultural surpluses and wastes increase in number and scope.

Mr R. A. Silow

With respect to the reference by an earlier speaker that the maintenance of living collections might eventually become an international consideration, it may be remembered that a 'Committee on Plant and Animal Stocks,' with interests similar to those of this meeting, has recently been established in the United States under the chairmanship of Dr Walter Landauer, Poultry Geneticist at the University of Connecticut, Storrs, Connecticut, U.S.A.

The appropriate international organizations which might be interested in this matter appear to be UNESCO and UNFAO. If it does come to be considered by these bodies, we should see that our respective governments give the project full support. The problem of maintenance of breeding reservoirs is an urgent one, on both scientific and economic grounds, and becomes increasingly so as breeding programmes become more extensive and more successful in attaining their immediate objectives. It can never be too early to commence taking measures to ensure the perpetual retention of a full cross-section of the variability of each of our domesticated animals and crops, and it is a responsibility of this generation of scientists. We must think of this problem in terms of the only scientifically justifiable scale, and that is a world scale, and I believe that the passage of a resolution emphasizing the importance of this matter by this Conference, and transmitted to the two United Nations organizations concerned, would give them the authoritative backing which they are likely to need if the subject comes up for their consideration. In the meantime, such a course would not relieve the British Commonwealth of its responsibility for taking the necessary steps to safeguard its own interests in the matter, on its own initiative.

Dr H. H. Storey

Dr H. H. Storey stressed the dangers involved in transferring living plant material from country to country, particularly in view of the evidence that many apparently healthy plants could carry viruses that might pass to, and damage other species or varieties of economic plants. Nevertheless progress demanded such transfer, although it should be kept down to the minimum possible. The measures to be taken to reduce the risk had been laid down in a series of mycological conferences before the war. Of these the speaker regarded as most important the constant inspection by competent pathologists of the plants during growth in quarantine; and for this reason quarantine stations should be sited with due regard to their accessibility to qualified staff.

Dr E. B. Worthington

Dr E. B. Worthington (Development Adviser, Uganda) suggested that many plants and animals were introduced to various parts of the Empire because we are still so ignorant about the indigenous fauna and flora, some of which might serve functions as good as those claimed for the introduced species. He instanced the case of fish from North America which are now becoming widely distributed in Southern and Eastern Africa, perhaps bringing diseases and other troubles with them.

Referring to Sir Edward Salisbury's paper, Dr Worthington pointed out that the next ten years would see a greatly increased potential for applied biological research in the Colonial Empire, but that no provision had yet been made for the fundamental biological studies in taxonomy and ecology, on which the applied work must depend. He suggested that the days of the short-term biological expedition were past, except when undertaken for specific purposes, and that the need is now great for permanent study of fundamental biology in the Colonies on a regional basis, linked with the large and long established centres in the United Kingdom and the Dominions. Unless arrangements for such work could be made in the near future, there would be danger of a lack of balance in using natural resources, and applied research would be delayed for lack of the fundamental background.

THE INTRODUCTION OF PLANT DISEASES INTO NEW ZEALAND

By Dr G. H. Cunningham

(Director, Plant Diseases Division, Department of Scientific and Industrial Research, New Zealand)

INTRODUCTION

In this paper, previously published in the *New Zealand Geographer*, an endeavour has been made to outline means whereby most of the 800 diseases with which our agricultural crops are beset were introduced into New Zealand. Upwards of 98 per cent of these, caused by insects, fungi, bacteria or viruses, have been imported from overseas countries, either in or upon seeds, bulbs, corms or tubers, in or upon living plants, or with timber or other plant products.

Collectively they adversely affect New Zealand agricultural economy and they seriously impair production of crops and fruits. Their presence has necessitated modifications in farm practices and the annual employment of costly remedial measures such as spraying of fruit trees, treating seeds with chemicals, etc., and it has also in many cases limited production of certain types of crops to localized regions where diseases are less troublesome.

Problems of exclusion of disease not yet present in the Dominion are discussed. It is held that rigorous quarantine measures, or restrictive legislation limiting imports of agricultural or garden produce, are impracticable. The conclusion is drawn that trade relationships with overseas countries would be least adversely affected, and further imports of plant diseases reduced, by making use of current knowledge concerning overseas disease distribution, limiting imports to areas in which serious diseases—not in the Dominion—were reported. Some system of quarantine of imported fruit trees and shrubs would still further reduce the risk of importing new diseases.

THE RAVAGES OF PLANT DISEASES

It has been claimed by some of our early settlers that in the good old days during the late summer and early autumn months they have seen the Waikato and Wanganui rivers carrying down to the sea large quantities of luscious ripe peaches, shed from trees growing upon their banks. Possibly this is an exaggeration; but the fact remains that from the 'sixties' to the early 'nineties' of last century the peach flourished exceedingly in warmer areas of the North Island. Once it was the most common of fruit trees, growing at the edge of Maori clearings in the forest, in back gardens and along roadsides and paths through the countryside. Trees were first raised from stones brought to New Zealand by missionaries

and early settlers ; they were subsequently grown so widely by the Maori that they became known as the 'Maori' peach. None survives to-day, all having been destroyed during the late 'nineties,' mainly by two diseases brought from overseas with later introductions of peach and nectarine plants.

This is not the only instance in which the yields of fruit and other crops have sadly diminished. There are indeed very many other examples of the ravages of plant diseases : many of them are of recent occurrence, and new diseases continue to arrive in New Zealand.

Farmers of an earlier generation could readily obtain a 10 or 15 ton per acre crop of potatoes. The average Dominion yield is now about four and a half tons, though in favoured and isolated localities where disease is less troublesome, and by use of certified seed, farmers may still secure 10 or 12 ton crops. Good milling wheat was once grown in abundance in various districts of Auckland province—in fact much of the flour then consumed was prepared from locally grown grain. To-day it is doubtful if a commercial wheat crop is grown in any part of the province.

About 15 years ago some 500 acres of strawberries were fruited annually near Auckland ; last year barely 80 acres were under cultivation. Formerly fruit could be purchased at about 6d. a 'chip' of approximately one pound in weight ; in 1944–45 prices did not fall below 3s. 6d. a pound, because of this scarcity. As recently as seven years ago passion vines could be cultivated upon any fence or hedge, or grown commercially upon wires or other support in the warmer parts of the North Island. Nowadays a commercial crop is possible only when vines are regularly sprayed to combat diseases which destroy the fruits.

Numerous other examples could be cited. Enough has been written, however, to show that fruit and farm produce were produced more easily in the earlier phases of the agricultural life of the Dominion. This change, though of gradual onset, has been brought about by accidental importation of plant diseases. Could they have been excluded from the country, our agricultural practices would have been different, and fruit and vegetables and farm produce would have been more plentiful and considerably cheaper.

NEW ZEALAND'S ISOLATION NO DEFENCE

With such an isolated country as New Zealand, separated from the large land masses of the globe by wide oceans, it might be thought that exclusion of overseas plant diseases would have been relatively easy. Such, unfortunately, has not been the case, since nearly all of the 800 or more common diseases which attack our plants are of foreign origin. Year by year they have gained entry through our ports, a few at a time, despite restrictions designed for their exclusion. More are arriving each year. As means of transport are speeded up, many others will gain entry unless more rigorous measures are provided for their exclusion.

Each new entrant, if sufficiently destructive to warrant the use of special control measures, adds to costs of production of the plant attacked. Roughly, it costs a commercial grower about 1s. 6d. a tree to combat

diseases in his orchard, diseases which if unchecked would render his crop unmarketable. Tomato growers are taxed directly about 2d. a pound for glasshouse fruit. The commercial vegetable grower may have to spend as much as £10 an acre per crop to secure marketable produce. More serious still are some field crop diseases. The acute potato shortage of 1944 resulted through ravages of late-blight in southern crops. Dry-rot and club-root so limit production of swedes and turnips—important supplementary winter feeds—that the potential sheep-carrying capacity of the South Island is reduced by at least one-third.

THE TRANSMISSION OF PLANT DISEASES

Plant diseases are caused by numerous agencies—insects, fungi, bacteria, viruses all taking annual toll. They may be carried from one country to another, or from district to district within a country, by various methods. So far as we know, all have been brought to New Zealand by one or other of those listed.

One group is carried upon, or within, the seed of their hosts, examples being the fungous diseases producing smuts of cereals, dry-rot of brassicas, celery leaf-spot, browning of linen flax, and the bacterial grease-spot of beans. Whenever a crop of wheat or oats, swedes or turnips, celery, linen flax or beans is grown from infected seed, diseased plants appear and from them the disease is dispersed by agency of wind, insects or cultural implements.

Others are carried upon or within the living plant, or soil adhering to its roots. Plants imported by nurserymen are set out in the nursery to provide material from which commercial trees may be propagated for sale. When present, diseases spread to related plants in the nursery, and with the latter are carried throughout the country. Diseases which exterminated the Maori peach—die-back and leaf-curl—were brought to the Dominion in this way. Citrus-canker was accidentally introduced in 1934 with a few ornamental citrus plants imported by a nurseryman from Japan. Young lemon trees became infected in the nursery and when sent to orchards in the citrus-growing districts of Keri Keri and Tauranga, infected healthy plantations of oranges, lemons and grapefruit. Dicky rice-weevil was introduced to an Auckland nursery from Australia in soil at the roots of peach trees. From the nursery the pest was carried to citrus areas in earth adhering to roots of balled citrus stock. White-butterfly was carried to the shores of Napier harbour in 1930 with cabbages thrown from the galley of an anchored British ship. It became troublesome the following year in vegetable gardens in the neighbourhood, and subsequently has spread throughout the Dominion.

Many diseases are carried within tubers, bulbs or corms. Some of virus origin have been imported by this means. Crops of potatoes grown in the early days were probably free, or almost free, from virus diseases. With importation of new varieties the virus population has been built up gradually until to-day there are about a dozen known to infect commercial crops. Spread from infected to healthy plants by aphides or thrips, infection has now become general, with consequent gradual but continuous reduction of yields. The only known control is by rogueing, removing

diseased plants that tubers from healthy ones may be used for seed. Virus diseases are mainly the cause of degeneration of strawberries, the remedy being to remove infected plants from the nursery beds. Onion-smut was brought to New Zealand in 1926 with a shipment of onions from Canada. Because of their excellent quality, a few bulbs from the shipment were planted for seed by two growers in the large onion producing centre of Marshland, near Christchurch. Soon firmly established, onion-smut spready rapidly so that growers are now forced to practise costly annual remedial measures to ensure a crop.

An unusual means of dissemination is that of our most serious virus disease of tomato and tobacco. The virus is present in most brands of smoking tobacco, and able to persist therein for many years. Smokers engaged in pricking out seedlings into nursery beds or boxes, after handling

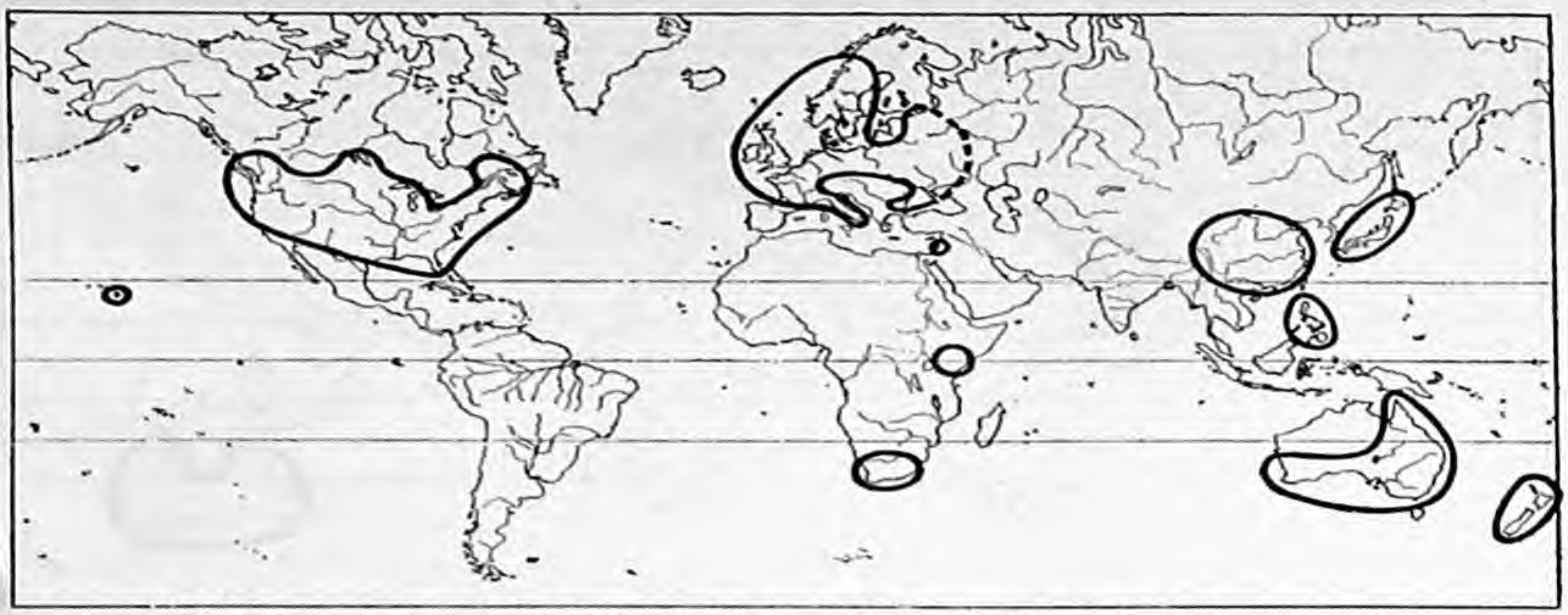

Fig. 1. Map showing wide distribution of the seed carried dry-rot disease of brassicas. Note that it is present in all regions where these hosts are grown commercially. (*After Imperial Mycological Institute.*)

smoking tobacco, inadvertently infect some dozens of seedlings before infection is removed from their hands. During the practice of lateraling, infection is further spread in the field from diseased to healthy plants. The remedy is simple, but difficult to enforce since few workmen will forgo their smoke while working, or trouble to wash their hands thoroughly with soap and water after handling tobacco.

Three species of termites were brought to New Zealand in the interior of hardwood power poles and sleepers imported from Australia. From these initial infection centres they became established in several localities in the North Island. They spread gradually to dwellings and other wooden buildings, causing such extensive damage that special legislation was introduced in 1940 to enforce eradication of the termite colonies.

DIFFICULTY IN EXCLUDING PLANT DISEASES

Exclusion of plant diseases from an importing-exporting country presents many problems. In some regions an elaborate and costly quarantine

system has been devised to achieve this end. In the United States of America, for example, no plant or plant product is permitted entry save through official quarantine stations. Seeds are first disinfected, then grown to maturity in special insect-proofed glasshouses. The progeny is resown and plants again grown to maturity before seed is released for distribution. Diseased plants are destroyed. With plants, a part is budded or grafted to stock grown under glass. Part of the resultant tree is again worked to another stock so that no part of the parent plant survives.

Such elaborate measures are not possible in New Zealand or, in fact, in any region dependent to a large extent upon agricultural exports. For they would adversely affect trade relations with overseas countries and require, furthermore, that the Dominion become self-supporting in production of agricultural, vegetable and flower seeds, potatoes, bulbs, etc.

Fortunately in most overseas countries there exist excellent plant disease

Fig. 2. Map showing limited distribution of blue-mould of tobacco. (*After Imperial Mycological Institute.*)

research organizations which record in current periodicals relevant information concerning host range, geographic distribution and climatic factors influencing development of disease.

Certain diseases attack only one or at most a few varieties of a specific host plant ; others may infect all varieties of a species ; others again many species of a genus ; still others several genera in the host family ; while a few are able to infect almost any plant, given favourable climatic conditions. Those attacking tropical crops such as bananas, sugarcane, cotton, tea, coffee, rubber or rice are almost entirely of academic interest since most are confined to their host plants which are not grown on a commercial scale in the Dominion. Diseases of importance to the New Zealand farmer and fruitgrower are those attacking crops of the mid-latitudes. Records of their distribution are readily available. Recently the Imperial Mycological Institute, Kew, England, commenced an issue of excellent distribution maps of the plant diseases of the world. They show at a glance both the regions in which specific diseases occur and their host range (Figs. 1, 2).

Use is made of such information by the plant pathologist in weighing the probabilities of additional diseases being imported. By limiting imports of certain plants or plant products from specific areas he is able to reduce the risk to a minimum without materially upsetting trade relationships, in the full realization that it is impossible to prevent accidental importation of all diseases, however elaborate the machinery set up for their exclusion. Small packages of flower and vegetable seeds, bulbs or tubers are often sent through the post from abroad, or brought in with passengers' baggage. In times of scarcity large shipments of fruits, vegetables or cereals are permitted entry without adequate inspection or consideration being given to their place of origin. All may carry diseases which might spread to commercial crops. And no legislative or quarantine measures, however elaborate, will prevent fortuitous entry of diseases in the manner in which white-butterfly made its unwelcome appearance.

THE COLLECTION AND INTERCHANGE OF SCIENTIFIC RECORDS AND EXPERIMENTAL MATERIAL AND SOME SUGGESTED SAFEGUARDS TO MINIMIZE THE RISK INVOLVED IN THE DISTRIBUTION OF BIOLOGICAL MATERIAL

By Khan Bahadur Mian Mohammed Afzal Husain and Professor J. N. Mukherjee, C.B.E., D.Sc.

This item may be discussed under the three heads :—

1. Collection and interchange of scientific records,
2. Collection and interchange of experimental material, and
3. Suggested safeguards to minimize the risk involved in the distribution of biological material.

1. Collection and interchange of scientific records

In so far as the publication of scientific work is concerned, various scientific and specialized journals provide the necessary machinery for intercharge of available information. One improvement that can perhaps be suggested is in the direction of some reduction in the number of such journals and in the variety of the languages in which they are printed. Again a large number of journals, particularly the proceedings of the learned societies, publish contributions on such a variety of subjects that sometimes very useful and important information, on a particular branch of knowledge, gets buried amongst miscellaneous material and is frequently lost. Further, need has been felt for a more definite demarcation between journals publishing results of original investigations and periodicals whose main object is the dissemination of information in popular language. It is difficult even for a central library of a country to obtain all the numerous journals relating to the biological sciences, leaving aside the other sciences.

Journals which *review* or *abstract* information are most helpful in providing in a handy form a résumé of current scientific literature. Imperial Bureaux and Institutes and similar other organizations are rendering useful service in this field. Here again the multiplicity of *reviews* and *abstracts* is bewildering and it would be much better if means could be found to restrict the number. It would also be desirable to reduce the price of some of the *abstracts* and *reviews* to secure wider circulation. This may be done by subsidizing their publication from a common fund. In a country like India, where distances are great, isolated investigators find it difficult to obtain these most useful publications regularly.

The institutes or organizations which publish reviews and abstracts of current literature can increase their usefulness still more if they could reproduce in greater detail information of value from journals which are

not generally available, have limited circulation or are published in languages not widely understood. These organizations have been rendering useful service in interchange of literature, in supply of translations and publications of reviews and in answering queries. In this direction there is need for increasing their facilities. There is also great need for the publication of monographs periodically bringing information up-to-date on important problems and giving bibliography on such subjects.

Regarding unpublished records the position is a little difficult. Often such records consist of departmental reports and proceedings of committees which are usually marked ' confidential ' or ' for official use only.' Sometimes valuable records are thus made inaccessible to other workers. These documents should be carefully abstracted and if they contain no ' secret ' should be made available to genuine investigators engaged on these problems.

Experimental stations and *research institutes* are usually collecting routine data which are often not published. The investigators working elsewhere may, in many cases derive considerable information from such data. Again, in several instances it is after prolonged investigations that definite results suitable for publication become available, and in such cases it may be possible to avoid unnecessary duplication, effect co-ordination and obtain quick results if data concerning problems still under investigation can be exchanged. This may not be always possible and may sometimes lead to difficulties, nevertheless, it may be possible in certain circumstances to arrange for exchange of information between workers engaged on similar problems.

To obtain best results a wholesome system would be a direct interchange of information between the workers engaged on similar problems. This will not only be the most direct and quickest method but it will also provide personal contact between the workers. Perhaps it may be necessary to initiate such contacts through the directors of the institutes, who may permit subsequent interchange of correspondence between the workers themselves. There should be an implicit understanding in such cases that the results of investigations would be published with the approval of the collaborating workers.

To facilitate the exchange of records and information, it is necessary that each country should have a central organization possessing full information regarding the lines of investigations in progress in various institutes of its own country and elsewhere. Such organizations in different countries evidently shall have to remain in very close contact.

An interchange of really informative programmes of research particularly in the field of applied science is, perhaps, the most important aspect in the advancement of science. Such interchange would help to avoid unnecessary repetition and enable a concerted attack on a problem from different directions and in varying conditions. There are several problems of international importance which can be most effectively solved by simultaneous study at a chain of stations situated in different parts of the world. Co-ordination of programmes of research is likely to be of utmost value. Such co-ordination can be best obtained by mutual consultation between the workers or institutes. Liaison agencies may help to establish such contacts.

It must, however, be recognized that there is grave danger in over-co-ordination. It may lead to regimentation and thus destroy initiative and originality. Administrative authorities may not readily countenance any departure from a programme laid down by an expert authority. Young workers may be tempted to follow the easier, conventional channels, and merely repeat what some one else is doing, or may unconsciously follow the lead of a senior investigator of repute. Self-effort may get stifled. Faced with a difficulty an investigator left to his own resources may exert himself to find a solution, but if advice and help are readily available, the necessary mental effort may not be forthcoming. Different investigators faced with the same difficulty are likely to evolve different methods to resolve such a difficulty, and are likely to obtain a variety of solutions. This variety leads to real success and provides for the selection of the best solution. It will be a great calamity if too much advice and co-ordination kills the true spirit of inquiry. There is greater danger for countries which are building up the true spirit of inquiry.

2. Collection and interchange of experimental material

There is considerable room for improvement in the facilities for the collection of experimental material. Any inquiry based only on locally available material remains incomplete or provides an answer of mere local application. Through mutual exchange of material and observations, the scope of an inquiry gets enlarged and sounder results of wider application are obtained. Interchange of material for experiments should be encouraged by every means. There are numerous problems which are of international importance. In fact there are very few big problems which are not of world wide importance. For instance, a commodity such as cotton produced in India is utilized in England for the manufacture of cloth. Lac, of which India holds the monopoly, is mainly used outside India. In the production of such commodities the countries that produce and the countries that use are equally interested. Interchange of information and experimental material, therefore, is of great advantage. This is particularly true of plants and animals. Every country has in the past benefited from the introduction of new varieties of plants and animals. The progress, however, has been slow. The reason being the limited scope for trials. Extensive interchange of types, strains, races of plants and animals for experimental purposes may lead to the introduction of useful crops and animals on a larger scale than has been the case so far. Producing a new variety is a laborious task, and when such a variety as shows improvement has been produced it should be spread. Again a variety which is discarded as unsuitable for a particular locality may prove to be of great value in another locality, where conditions are different. If information about the problems under investigation in different regions, material available for exchange, and material required, is available, it will facilitate mutual interchange. In every country there should be an agency which maintains full records and undertakes to bring about exchange of experimental material.

For collection of fresh material international organizations should be set up. Encouragement should be given to young workers from as many countries as possible to join in expeditions for collecting material.

3. Suggested safeguards to be taken to minimize the risk involved in the distribution of biological material

It is very essential that proper safeguards are taken in the interchange of experimental material of the biological workers. The danger lies in three directions, viz. :—

(*a*) introduction of new pests and diseases of plants ;
(*b*) introduction of new diseases of animals ;
(*c*) imported plants and animals developing themselves into weeds and pests respectively in the new country.

Regarding (*a*) it is necessary that all the imported materials should be examined and suitably treated before their dispatch from the country of origin and before entry into another country. A number of most injurious pests and plant diseases have been introduced into India with imported materials. The notorious pests codling moth, San Josê scale, woolly aphis, etc., may be named in this connexion. Up till now the Government of India had no proper organization to stop the entry of such foreign pests and diseases into this country. Fortunately, however, it has now been decided to organize a Plant Protection and Quarantine Service which will examine all imported plants, seeds, flowers, fruits, etc., at seaports, land frontiers and aerodromes. In the case of any material found infested proper measures will be taken to treat such material in a suitable manner before it is allowed to go into the interior.

(*b*) As regards the introduction of new animal diseases precautions have to be taken against the entry of bacterial and other diseases of silk worms, honey bees, poultry, cattle and other livestock.

Sometimes plants, seeds and animals do not show at once any visible sign of being infested. It is, therefore, essential that arrangements should be made to keep suspected material under quarantine. The plant protection and quarantine organization referred to above is contemplating establishment of such quarantine stations in various parts of India where imported materials could be kept under observation and watched for the appearance of any disease.

(*c*) As regards plants and animals introduced without careful thought and their ultimately developing into weeds or pests, the classical example of lantana and water hyacinth into India and of the rabbit into Australia are well known.

There is another way by which introductions may do harm rather than good. This is particularly true in the case of parasites which were introduced in some parts of the world with the purpose of controlling pests. Actually, however, these parasites disturbed the existing balance in such areas and interfered with the work of the parasites which were already doing some good and thus the newly introduced parasites proved ultimately injurious from economic view point. For example, it is held that *Opius humilis* was doing good work in Hawaii, but with the introduction of *Diachasma tryoni* the parasitization of *Opius* decreased and *Diachasma* ceased to do any good. Similarly *Eupelminus saltator* (parasite of the Hessian fly) interfered with the work of *Apanteles melanoscelus* (parasite of the gypsy moth). There are numerous other examples of the competition of new parasites with those already existing in the country.

THE COLLECTION, PRESERVATION AND INTERCHANGE OF BIOLOGICAL MATERIAL

By Sir Edward Salisbury, C.B.E., Sec.R.S.

The collection, preservation and interchange of biological material to serve scientific and economic ends presents a number of problems that merit our consideration. In so far as we can increase efficiency to serve imperial needs to that extent we shall have learnt to solve the wider problems of global science. If, however, we are unable to solve these questions within the narrower limits of those with a long experience of co-operation in both the scientific and political fields we shall be unable to attain that international co-operation and service which must be the aim of all scientific endeavour.

As a matter of practical expediency only, it will, I think, be convenient to consider living material and dead material separately, and, again for practical reasons and with even less scientific justification, it will, I think, be advantageous to consider material which is mainly of scientific interest separately from that which has a large or preponderantly economic value.

First, as to the scope of collections. Ideally, I suppose the chief collection in any one area should contain specimens of plants and animals of every group and of every species so far as these are obtainable, but the doctrine of complete self-sufficiency is as biologically unsound as it is politically barren. Moreover, it is quite impracticable to contemplate such gargantuan depositories and inflated staffs as this would demand. In practice some measure of specialization does in fact often obtain, but it is not so much part of wide and avowed policy as a matter of *ad hoc* expediency. If I may take as an example the herbarium of my own institution, this already houses some six million dried specimens of flowering plants from all over the world, and contains some 240,000 types. It is thus cosmopolitan in scope, international in interest, and the value of such a collection is attested by the numbers of distinguished botanists from all parts of the world who in normal times are to be found working within its walls. But outside the confines of the phanerogams, the Kew collections are also world-wide and extensive. Should Kew try to cover all groups of plants or should some groups be regarded as the specialities of other institutions ? For every *national* botanical, zoological or geological collection throughout the world to be international and ' extensive ' in character is quite out of the question both on grounds of finance and personnel. It is, I think, therefore worth while discussing :—

(*a*) What provision on scientific grounds is requisite for collection of cosmopolitan ' extensive ' scope for collections of non-living :

(i) botanical material
(ii) zoological material
(iii) geological material

(*b*) Whether for each of these fields of study the 'extensive' institutions should be all-embracing or only cover parts of the subject. If the latter, what should be the basis of subdivision.

For institutions not aiming at 'extensive' cosmopolitan collections over a large part of the whole of the subject, what principles should govern their particular specialization? Should the division of labour be regional or taxonomic? The latter would be the more scientific basis but the former would often prove to be both more practicable and more useful, and should, I feel, be adopted as the basis for all herbaria regarded as of a *national* character. It would for instance facilitate the preparation of regional faunas and floras. Institutions having as their policy specialization in particular groups or areas might naturally be expected to attain a completeness of material far greater than that provided by the extensive type of institute (except where these too elected to specialize in certain groups) and could afford to provide more adequately for monographers of the particular families and genera which they had chosen as their intensive features.

In the past the provision of the requisite facilities has been somewhat haphazard, depending partly on the presence of a member of staff with a particular bent, partly on the whim of private benefactors. But with the increased facilities and financial provision that modern research demands the specialist will inevitably tend to gravitate to where these requirements are met. Hence the marriage of men and material will be most readily achieved by the adoption of some measure of specialization and division of labour. The acceptance of a definite policy of this character as part of a co-operative scheme would restrict the freedom of institutions only in so far as it imposed responsibilities in respect to specialization voluntarily accepted, but these responsibilities would on the other hand constitute a claim on support from public funds as an essential part of a national, imperial or even international need, such as could not be made for a policy of replication.

Almost every public museum and herbarium serves a dual purpose, both as a repository of material for research and as an instrument of education, but these aims have often tended to be confused, so that public galleries are liable to produce upon the visitor a palimpsest of uncoordinated impressions. This dual function needs to be fully recognized in organizations for research and public display. But whilst the two functions might well be segregated within the same institution, the educational aspect inevitably implies some measure of extensive collection whatever the degree of intensive specialization with regard to accumulation of research materials. What specialization any particular institution can afford to offer for the common good it alone is probably in a position to decide. But that a stated and co-operative policy with respect to taxonomic institutions would be beneficial to the progress of science, and ultimately to the institutions themselves, is, I think, beyond dispute.

The vast extent and growing recognition of the importance of the insects raises the question as to how far this group can be properly provided for in a general zoological museum, and whether the time has not come when the general biological museum is more appropriate as an instrument

of education than as a repository where research material is stored and investigated. It may here be appropriate to emphasize that adequate accommodation and equipment for research should be provided in all museums.

The collection of soil profiles in connexion with soil survey will in the future present problems of accommodation and taxonomy in an acute form that, like the cognate problems of geology, require a survey of the possibilities of co-operative action.

Modern rapid transport by air makes an integrated network of collections more practically useful, if special financial provision for the necessary travel be made available. For example, such an integration would be facilitated if opportunities were provided from time to time for the directors of cognate institutions to meet together and discuss problems of common interest and measures for improved co-operation. What I suggest we might recommend is that each institution be asked to state its proposed policy in respect of collections and for what groups, if any, it is prepared to accept special responsibility. Only then can we know the extent of overlap and the gaps remaining to be filled.

In the taxonomic field type specimens are all-important, and in view of the losses sustained during the recent war it is appropriate to raise the question whether microfilms of all types and other specially important specimens should not be made available. Institutions possessing types in groups for which they do not make ' intensive ' provision should, if possible, provide co-types to the specializing institution or such photographs, casts, etc., as may be practicable. Collections of economic products present similar problems to entire organisms. We have at Kew extensive collections of plant products of all types. The Forest Products Research Station has collections of a more restricted and intensive character. The question might usefully be discussed as to whether the provision of specialized collections is inadequate and if so in what respects.

Turning to the problem of living collections, these serve not merely taxonomic ends but provide material for physiological, anatomical, cytogenetic and breeding research. The lower organisms have to be maintained in pure culture like the type collections of bacteria and moulds at the Lister and the collection of protista at Cambridge. How far ought such collections to be extended and if so to what groups ? Air transport should make it practicable for one collection of each group to serve the whole Empire. What can be done with respect to viruses ?

Living collections of the higher plants are provided for on an ' extensive ' scale at various botanical gardens. At Kew, for instance, the living collections comprise some 40,000 species, but here and elsewhere the question is what ought we to strive to achieve. The maintenance of the vast collections at Kew is a task requiring a large staff of highly skilled horticulturists. The more complete the collection of species in any one genus, the higher proportionally usually becomes the skill and labour requisite for their maintenance. In general, Kew adopts the plan of growing the rarer species and those more interesting, whether botanically or horticulturally, but we endeavour to amass all the available species of a genus when there is research being carried out upon them. But, here too, it might well be desirable that each botanical garden should make itself responsible for

particular important genera for which its circumstances are peculiarly suited, so as to relieve others of the necessity of their maintenance, except in so far as another botanic garden may wish to do so. In each region the provision of adequate nature reserves should supplement species preservation in institutions, particularly as collections in botanic gardens tend to include a preponderating proportion of exotic species. The poor representation of native species is a general defect of botanical gardens and one reflected in their seed exchange lists. Kew is no exception, but it is a defect that should be remedied, so far as the more interesting species are concerned, as soon as possible.

In the realm of important economic genera and species, collections as complete as may be are eminently desirable as sources of genetical material as well as from other aspects. When it is recalled that there are many varieties of millets, many thousands of rice, thousands more of oats, probably nearly 30,000 varieties of wheat, etc., it is obvious that even on the grounds of care and space alone, specialized collections and some division of labour are desirable.

Lord Hankey's Committee in 1943 made the suggestion that by arrangement between the experimental stations in the British Commonwealth they severally should undertake to maintain live collections of particular crop species and varieties according to the suitability of their respective environmental conditions, and thus provide sources from which the taxonomist, the geneticist and the plant breeder could obtain the material for their researches.

This recommendation has been in part implemented. Thus the collections of cotton are to be maintained in the Sudan by the Empire Cotton Corporation. Varieties of *hevea* rubber will be assembled at Kuala Lumpur in the Federated Malay States by the Rubber Research Institute. Cacaos it is intended to assemble both in Trinidad and in the Gold Coast at Tafo. Collections of bananas have already been assembled in Jamaica as well as by the Imperial College of Tropical Agriculture in Trinidad, these it is intended to extend as soon as circumstances permit. Collections of sugarcane and allied species are maintained in India, Barbados and Mauritius; though these need extension. Tea collections exist in Assam at Tocklai. A beginning has been made at the Oil Palm Research Station at Benin in Nigeria to make an oil palm collection, and a collection of coconuts is to be made at the Coconut Research Station, Ceylon. For coffee, suitable locations would be at the research stations in East Africa and Southern India.

Such collections require adequate land, adequate staff for their maintenance and not least sufficient funds both to ensure their proper development and their effective utilization. It is most undesirable that the efficiency of the main requirements in this respect should be prejudiced by any attempt to develop and maintain collections beyond the reasonable capacity of personnel and material provision available. Ideally, we ought to collect everything that is of economic importance and scientific interest, for who can foretell that what appears to be a useless species or genus to-day may not, like *Penicillium notatum*, be of prime importance to-morrow.

The maintenance of large collections of annual species or even of short-lived perennials makes great demands upon labour, and except for species

that are normally self-pollinated, the requisite safeguards against cross-pollination involve skilled supervision and wide dispersal. It is important therefore to assess the problematical value of complete varietal collections of economic species against the labour and cost of efficient maintenance. We must ask ourselves whether the necessary financial provision and staff could be utilized to better advantage and whether there may not, for instance, be a desirable compromise involving selection, such as representatives of all the sections into which the strains of a species can be grouped, together with such others as there is reason to believe furnish marked characteristics either desirable in themselves or likely to be of value for the plant breeder. It can, of course, be quite rightly argued that no one can accurately assess the potential value of any given strain, yet many such could be discarded with little risk of losing valuable characteristics. If, however, it be agreed that practical considerations impose some measure of restriction, it is desirable to formulate so far as is possible the general principles that should govern the selection which should comprise the standard collection of any given species.

It is a matter for discussion which genera should be selected as meriting the maintenance of 'intensive' collections of species and varieties and the principles that should govern their location. The particular genus may be under investigation in an area which is not the most suitable to the maintenance of a collection and, moreover, with changes of personnel there are liable to be marked changes of emphasis at research institutes. So that permanent attributes such as freedom from disease and ease of maintenance of healthy stocks in other respects should govern location of such collections rather than the ephemeral circumstances referred to. Some one centre should be responsible for each of the economic genera regarded as of sufficient importance to warrant this intensive maintenance, and steps must be taken to ensure that the material sent out for research purposes from the collections is free from disease. Another subject that merits discussion is the steps that can be usefully taken to avert the risk of the introduction of pests and diseases on living material, whether of wild or economic species. The establishment of plant quarantine stations requires further consideration. Some exist already, but others may be necessary. Where carriers of virus diseases are concerned, only experiments can demonstrate the undesirable nature of an introduction.

What has been said above respecting plants probably applies also to economic species and varieties of animals. Here, too, the maintenance of pure strains for physiological purposes has been in part provided for in this country at Compton, but a general policy directed towards attaining the ideal in respect to animal material, especially that required for standardized experiments, is requisite. Some fine herds of Indian breeds have already been built up in India and selection from indigenous breeds in Africa has already begun. More work in this connexion is, however, necessary if livestock problems in the tropics are to receive the attention which their importance warrants.

The following questions therefore appear to merit discussion :—

1. What should be the scope of 'extensive' taxonomic collections, and how many does the Empire need in respect to zoological and botanical

material? Should, for example, the higher animals be dealt with in the same institution as the insects, the phanerogams as the lower plants?

2. (*a*) Should collections of a *national* character be regional and institutional collections relate to taxonomic subdivisions?

(*b*) Should all taxonomic institutions be asked to state their avowed scope and policy, especially as regards intensive activities they are prepared to undertake?

3. To what extent are 'extensive' collections of soil profiles desirable? or should these be regional only?

4. Should research facilities and public educational facilities be segregated activities?

5. Should steps be taken to distribute by means of microfilms, casts, etc., such data respecting types as may be possible to all the major regional taxonomic institutions so far as is relevant to their respective scope?

6. (*a*) What economic groups should be represented by living collections and what principles should be adopted as a measure of restriction of their size to practical limits?

(*b*) What are the most appropriate locations of the groups selected under (*a*)?

7. For what groups of lower organisms should living type collections be maintained?

8. To facilitate transfer with the least possible danger of spreading pests and pathological diseases, should a policy of regional plant quarantine stations be recommended and an extension of the provision of such stations be advocated?

9. What effective steps can be taken to minimize the danger of distributing virus diseases in plant material?

10. What steps are necessary to build up collections of livestock—especially for tropical conditions?

THE COLLECTION, PRESERVATION AND INTERCHANGE OF EXPERIMENTAL MATERIAL IN AUSTRALIA

By Dr H. C. Trumble, M.Agr.Sc., D.Sc.

This covers plant material that may be required for the investigation and mastery of pastoral, agricultural and horticultural problems including cultures of fungi and bacteria needed for microbiological researches.

So far there has not been established any appropriate organized service for international exchanges of plant material.

Plant introduction in the earlier phases of development of the newer countries such as Australia was effectively undertaken by the various botanic gardens, the activities of which were initially directed by competent botanists of world renown. The work undertaken was frequently most extensive and resulted in the importation of many valuable forms which supplemented the introductions of pioneer settlers themselves. As seen from the viewpoints of to-day, the work was mainly systematic and lacked both the ecological perspective and practical experience now available.

So far as Australia is concerned, the botanic gardens have gradually lost their function in this regard, partly following the development of the Departments of Agriculture and organizations established to engage on agricultural research, but also in large measure because the gardens themselves have remained static at the level of the nineteenth century when their pioneer work was largely performed. The Directors of these gardens have come to be appointed less for their botanic qualifications than for their capacity to preserve in terms of horticultural efficiency the scenic beauty and amenities of the gardens for the benefit of the public at large. In fact, the educational value of such gardens has tended to decline considerably.

On the other hand, Departments of Agriculture and centres of research on plant problems are usually interested only in specific questions sometimes of more or less temporary interest and it may be difficult to argue that they have a permanent function in the maintenance of comprehensive living collections.

The main hurdle to be negotiated is that bound up in the necessity for dynamic treatment of living collections involving their being grown repeatedly to maintain appropriately fresh stocks.

It would seem that the resuscitation of the botanic gardens as custodians of economically useful material and centres of popular education concerning the practical use of such material might be earnestly considered.

So far as the importation of new material is concerned, Australia has relied very largely on the explorations of other countries and the collection of stocks without active participation in the field of her own agricultural scientists. The time appears now to have arrived when she could with

advantage to her own economy and that of scientific progress generally encourage active exploration in overseas countries with climatic conditions comparable in a general way to those of the different natural regions of Australia. The centres to which exploration could most profitably be directed are (1) South America, including Chile, the Argentine and Southern Brazil, Uruguay and Eastern Paraguay, (2) the Mediterranean region, especially the eastern portion from the Balkan Peninsula to Trans-Caucasia and Palestine and (3) the tropical and sub-tropical regions of Africa.

Convincing arguments can be brought forward to support proposals that organized exploration should in the near future be conducted in these regions. Plant material for use in pastures is primarily required but there should be no limit to the forms collected whether for this purpose, for immediate testing as agents of field crop, horticultural and vegetable production, or for use in breeding programmes, aimed at increased disease resistance or other forms of improvement.

It would be highly desirable that such explorations be organized on an Empire basis if not on an international basis with representatives from the principal countries interested.

The treatment and care of the collected material is important. In the case of herbage plants at least, actively growing vegetative material is often the best form in which the field selections are made and this may require the use of temporary growing-on centres at which seed can be produced for subsequent dispatch. Special precautions to prevent the introduction and spread of disease are implicit.

It is suggested that some active centre of research should be closely associated with the collection and subsequent preservation of each specific collection and the selection of particular centres would not be difficult ; but the subsequent preservation of the stocks could well be the responsibility of the botanic gardens with requisite provision of liaison and supervision from the research centres concerned.

Special facilities including appropriate refrigeration space will need to be provided by arrangement with the shipping companies ; quarantine precautions could be covered by an arrangement between authorities at the port of entry in conjunction with the immediate growing-on centre at which both pathological and entomological control and supervision would be needed.

The project is obviously one for organized co-operation, and discussion should bring out standard lines of approach and measures of control that would be acceptable to the different countries concerned.

SCIENTIFIC RECORDS

The personal factor is all important in the interchange of unpublished material. Mutual confidence must be established and information should be imparted only on request and not under routine arrangement, which is best confined to officially endorsed publication, that can dispense with informal contact. The latter could well be fostered in principle, but its consequences will depend almost entirely on personnel, among whom arrangements for exchanges of unpublished matter are likely to develop

spontaneously, if meetings for discussion on topics of common interest are sufficiently encouraged.

In regard to publication, so far as agriculture is concerned there is room for an International Journal of Agricultural Science, to which could be affiliated the existing *Empire Journal of Experimental Agriculture*, the *Journal of the American Society of Agronomy* and any additional journals representing particular countries or groups. The *Empire Journal* as it now appears would provide a satisfactory foundation for needs within the Empire but requires to be modified both in title and orientation. With this could be affiliated in turn, journals of agricultural science for Canada, Australia, New Zealand, South Africa, India and other portions of the Empire. Tabular matter could be collated by the editorial facilities of each and issued as supplements at any of the different levels according to the degree of local or international significance.

MORNING SUBJECT (j)

DISCUSSION OF THE PROBLEMS OF LAND UTILIZATION AND CONSERVATION THROUGHOUT THE EMPIRE. THIS DISCUSSION IS DESIGNED TO BRING TOGETHER THE VARIOUS FACTORS AFFECTING LAND UTILIZATION AND CONSERVATION INCLUDING FORESTRY, SOIL EROSION, IRRIGATION, ETC.

STEERING GROUP

Chairman—Sir Theodore Rigg

Recorder—Mr G. V. Jacks

Brigadier R. A. Bagnold, F.R.S.	Professor J. N. Mukherjee
Mr A. Glendon Hill	Dr L. T. Nel
Professor E. S. Hills	Dr R. Newton

REPORT

The following were among many interesting points emerging during this discussion.

The importance of paying proper attention to the sociological element in planning long-term soil conservation was emphasized. Conservation involved the maintenance of soil fertility. This, though appearing to be an economic or technological question, became an issue of political importance when attempts were made to translate proposals into practice. Refusal to face up to the social and political implications of measures for soil conservation could only result in harm.

In Canada there was evidence of a general decline in soil fertility. Yields were falling, trace-element deficiency diseases were increasing ; the present widespread tendency to soil drifting had not been foreseen when the land was first cultivated and much more knowledge was still needed about the nature and distribution of Canadian soils and about land use in relation to food values. There was an appeal from Canadian delegates for a free interchange of information and of research workers among different parts of the Commonwealth.

In Australia water was the main factor limiting the productivity of the land. The great variability of the rainfall with its attendant hazards of drought and flood was important. Moreover, much depletion of soil fertility had resulted from overcultivation and overgrazing.

There was scope for a more systematic exploitation of the natural rainfall and for the introduction of legumes, followed by temporary leys. The immediate need was for soil surveys, research into water resources and methods of use, and the discovery of suitable herbage plants to produce a cover rapidly—particularly drought-resisting legumes.

The increase in population in India was producing a very serious situation with regard to depletion of soil resources. Nobody had a clear picture of how much damage had been done by erosion. There was urgent need to establish by survey the country's soil resources, the extent of erosion and the possibilities of irrigation. The social aspects were important. Much more information about the factors limiting the present low production of the peasant was needed. The farmer generally had more knowledge than the scientist—but less science—and objected to the somewhat dictatorial attitude of the Agricultural Department. Some form of land-use authority or soil-conservation service was required to ensure the co-operation of the farmers.

The basis of Government policy on land use in Great Britain was to avoid using good agricultural land for development purposes when other land is available. The aim of the Ministry of Agriculture and the Ministry of Town and Country Planning was to discover the optimal use of the land in the national interest. It was, however, impossible to have a positive land-use policy without a basic survey of land use, a knowledge of the reasons for that use, and an understanding of natural trends in land use.

South Africa was mainly pastoral, and most of the pastures were natural. It was essential to discover conservative systems of intensive farming. Legislation had been enacted putting responsibility for proper land use on the farmers. The State assisted with subsidies and only intervened by expropriating the land in the last resort. The human element was very important, particularly among the native population—e.g. the system of *lobolo* had been a direct cause of overstocking and veld deterioration.

Soil erosion in Southern Rhodesia had been tackled mainly from the engineering standpoint. Legislation had been passed giving the Soil Conservation Board fairly extensive powers over land use, but these powers could not be effectively used until the land had been properly surveyed.

In parts of Kenya large areas of fertile forest land had reverted to desert conditions within living memory. The pressing urgency of the problem in East Africa was emphasized and it was felt that attention here could well be concentrated upon the application of existing knowledge rather than upon the search for new knowledge. For conservation purposes, regions should be divided into national geographical units. Planning indeed should be based upon the region and not upon the village. Agriculture should be developed in each region according to its natural conditions and the pressure of population on the land could be relieved by the establishment of rural industries.

In New Zealand the programme for soil conservation was planned and carried out by the Soil Conservation Council composed of representatives of the farmers and government departments. River control was looked after by the Catchment Boards, on which the towns, the farmers and the government departments were represented.

The discussion in general emphasized the need for soil surveys as the foundation of national conservation policy.

General statement

In view of the gravity of the situation caused by the loss of and damage to the soil in many parts of the Commonwealth, the Conference attaches great importance to the carrying out of the following recommendations, with the help of trained agricultural scientists :—

(a) erosion surveys ;

(b) soil surveys ;

(c) investigations relating to the maintenance and improvement of soil fertility.

In addition to the above investigations, the Conference urges the importance of surveys to determine the present pattern of and trends in land use, as a basis for the maintenance of soil fertility, bearing in mind

the conflict between agricultural and other interests, including mining and industry.

In view of the similarity existing between problems of soil conservation in different parts of the Commonwealth, the Conference would emphasize the importance of a continuous interchange of information and the need for periodic conferences of specialist officers engaged upon problems of soil fertility, erosion and land utilization.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr E. S. ARCHIBALD

Two papers prepared in Canada, dealing with this subject and soil surveys and classification have already been distributed. I shall not repeat. There are, however, a few additional points which I shall mention.

1. Canada's vast land area of 3,700,000 square miles is often considered an index of her agricultural production possibilities. Actually only 173,000,000 acres or 271,000 square miles (8 per cent) are classified as occupied agricultural lands. Only extended soil surveys may determine additional areas which should be taken out of forest, but probably not more than a maximum of 50,000,000 acres.

Greater use of land by irrigation will not exceed 3,000,000 acres while drainage of muck soils and rehabilitation of diked lands may account for better use of another 1,000,000 acres.

2. On the other hand large areas of submarginal lands especially on the prairies are being taken out of cultural agriculture, reseeded, stack watering dams installed and organized for use by livestock grazing associations. Canada is not a land of unlimited agricultural lands.

3. Land conservation is now Canada's major problem. Crop production per acre is decreasing in spite of the fine research work of plant breeders, use of fertilizers and protective work of other scientists.

Erosion—sheet and gully—is increasing to an alarming degree. Wind erosion in our large grain areas although temporarily checked is a constant menace. More research on the methods of maintaining soil structure, renewing soil fibre is urgent.

Trace element deficiencies are becoming apparent and need intensive study.

4. Stocktaking of Canada's soils resources and decreasing fertility must be based on a completion of soil surveys and classification. On this a land use programme is being built and must be completed.

5. There are many allied fields requiring research such as : weed control, moisture conservation, more suitable machinery and implements and superior and more suitable crops, especially grasses, in a conservation plan.

6. The nutritive values of animal and human foods in relation to soils on which produced, deserves special research.

Finally—In all this much increased research, Canada needs the combined assistance of research stations and research workers in all parts of the Empire and the U.S.A. both in the use of their results as well as the training of our research workers.

Sir Lewis Fermor

Sir Lewis Fermor said that of the two branches of the subject under discussion soil conservation was, of course, desirable on its own merits; but it was much more desirable if the land so preserved was correctly utilized. He had been much interested in the maps exhibited by Dr Dudley Stamp of the utilization of land in Britain. As was well known there was often competition for the use of land in this country and it was important that in such cases the right use should be ensured.

No one had mentioned the conflict that sometimes arose between the mining industry and other interests. In 1938 he had gone to Malaya at the request of the Colonial Office to advise on the mining industry of that country. He found that in tin-bearing lands there was a contest between the miner and the Forest Department, the rubber industry, the agriculturist and the Drainage and Irrigation Department. For example, should fertile alluvial land containing valuable tin-ore be reserved for the cultivator or leased out for tin dredging? As such a large proportion of the revenue of Malaya was derived from export duties on tin, the miner had in most cases prevailed. But the result was silt in the rivers and destruction of land suitable for rice cultivation. On the question of silt he had found that assuming a very modest figure of an average loss of soil of only 3 inches depth over the whole of the rubber plantations of Malaya (some 3,300,000 acres) the contributions of silt to the rivers by the rubber industry had been twice as great as those of the tin industry, but they had been less noticeable because more widely distributed.

Then on the point whether dredged land was rendered permanently useless it was found that the Chinese could grow vegetables thereon, and that cocoanut palms had been planted in some places. It seemed also that rice could be grown where the silt was fine-grained. From the mining point of view it was also possible to strip the top soil and stack it separately for replacement after dredging had been completed. Whether this was financially feasible in any given case depended on the richness of the alluvium in tin and the depth at which the tin-ore occurred. In the opening up of fresh ground of agricultural value in the future no doubt the possibilities of rehabilitation of the land after dredging will be considered. Although the extraction of tin-ore causes permanent loss of land to agriculture, in some cases the long-term financial aspects of this on the economy of the country could be mitigated if the Government of Malaya implemented his (Sir Lewis's) recommendations that a Tin Revenue Amortization Fund be set up. All governments largely dependent for their finances upon the extraction of wasting mineral assets should take similar action.

Professor J. N. Mukherjee

Professor J. N. Mukherjee referred to the articles communicated to the Conference by Mr Afzal Hussain on subjects (*a*) and (*j*) which convey an idea of the problems of agriculture and of land utilization and conservation in India. The arable land available *per capita* in 1940–1941 was about 0·67 acres for a population of 400 millions, increasing at the rate of 5 millions per year. The conservation of soil resources and maintenance and improvement of soil fertility were for India matters of greatest import-

ance. It is very much necessary to reconcile the rival demands on land and to ensure that every bit of soil is put to its best use. Soil surveys and erosion surveys both require to be carried out more systematically. A land utilization survey is equally necessary so that an idea of the present land use pattern may be obtained and trends of its changes may be watched and adjusted. Local, regional and national aspects have to be reconciled in plans for better utilization of the land resources. Much information is available in areas of old settlements which however require to be collected and collated through such surveys. He particularly emphasized the part played by the rural population in schemes of soil conservation and land utilization. Without their active participation not much improvement is possible. Organizations of farmers should be developed and soil conservation circles established on lines similar to those which have been found so fruitful in the U.S.A. In this field pooling of information and exchange of workers within the Commonwealth will be of great value.

Dr John Nutman

In at least some of the isolated areas of dense population in East Africa conditions are now critical. An increasing population, with a tendency to a rising standard of living, is being maintained almost entirely on peasant agriculture. This can only be done at the expense of soil fertility. The consequences are as might be predicted—the extension of agriculture to marginal areas; the reduction of grazing grounds; over-cropping; and erosion. Certain important areas of East Africa are now in a state where complete destruction is imminent. This is quite inevitable under the present social and economic conditions.

Our present scientific knowledge is adequate to ameliorate conditions considerably, although research should not be neglected. To await the results of research before initiating action would be to risk the danger of final deterioration.

Remedies should be:

(*a*) The immediate application of present knowledge so that production can be increased and erosion hindered.

(*b*) The organization of a suitable district on regional lines as a large-scale experiment. The development scheme for this experimental area should make full use of natural resources and attempt to set up a state of affairs where erosion is not an inevitable consequence of improved living conditions.

Sir Theodore Rigg

After referring to two papers on soil conservation and land utilization presented by New Zealand scientists, Sir Theodore Rigg stated that although agricultural production had increased continuously since the settlement of the Dominion by the British people, striking illustrations of soil erosion were noticeable in different parts of the country. These were associated with (*a*) sheep farming on the native tussock lands of the South Island, (*b*) sheep farming on many steep slopes, under higher rainfall, particularly on the mudstone formations of the Hawkes Bay locality, (*c*) alluvial soils

on many of the rivers throughout New Zealand where erosion of high quality land and flooding problems were experienced.

Surveys conducted by the Soil Survey Division of the Department of Scientific and Industrial Research had shown that at least two million acres of the native tussock country in the South Island had been eroded to the extent of 50 per cent loss of topsoil. In certain cases this had been accompanied by great reduction in the carrying capacity of the land and in one instance the numbers of sheep on a grazing run of 250,000 acres had fallen to 15,500. Government authorities, soil scientists and farmers in New Zealand were alive to the necessity of controlling soil erosion and the following action was being taken :

1. Prosecution of erosion and soil surveys over all districts which were affected. Already soil erosion maps had been prepared for some 10 million acres of native tussock land.

2. Establishment of experimental stations on representative areas of eroded country in order to study methods of arresting soil erosion, management problems and the value of grasses, shrubs and trees.

3. Establishment of a central soil conservation and rivers control council for the co-ordination of all measures connected with soil conservation and for the prosecution of active work in the prevention of soil erosion.

Already great progress had been made in the establishment of catchment boards and regional soil conservation committees for the study of erosion problems and the conduct of control measures.

The importance of the correct use of land by farmers was realized by agricultural experts in New Zealand and land use maps were being prepared both in the Nelson and the Whangarei districts with a view to more effective and profitable use of the land.

Mr C. L. Robertson

The methods adopted in Southern Rhodesia for ensuring efficient land utilization and for promoting soil conservation may be of interest. Under the Natural Resources Act the N.R. Board can give orders to a landowner as to

- (*a*) Measures to be adopted to prevent soil erosion of his arable land.
- (*b*) Land which is not to be cultivated, e.g. in very steep slopes or within a defined distance of centres of depressions or valleys which form natural drainage channels and should therefore remain permanently under grass.
- (*c*) The number of stock that he may depasture on his holding. In the event of a landowner being unwilling or unable to construct the necessary protective works ordered under (*a*) the Board may arrange to have the works constructed and the cost is a charge against the property which is hypothecated.

Although these powers exist under the Act the Board has not exercised them to any extent, but instead the landowner is being induced to adopt proper methods and with this end in view :

- (*a*) Conservation Officers have been appointed by the Government who are available at no cost to the landowner for advice in the setting out of the necessary works.

(*b*) If the owners so desire the works will be constructed by Government owned mechanical plants on payment of a fixed scale of charges.

(*c*) The Government subsidizes the cost of construction of the works, e.g. contour ridges and stone drains to the extent of 33 1/3 per cent of the approved cost. This subsidy is also available for water conservation works. The ceiling is fixed as to the total subsidies payable on any farm or holding.

In order to encourage the adoption of sound farming methods the Government for a period of three years is paying an additional 2*s*. per bag for maize and 3*s*. per bag for wheat grown in accordance with certain defined conditions, viz. :

(*a*) The lands have where necessary been adequately protected by stone drains and contour ridges.

(*b*) An area equivalent to half the area under maize has been planted with a green manure crop which has been properly ploughed in or alternatively that compost has been prepared and is available for application to the land at a rate of not less than 5 tons to the acre.

In the case of wheat the whole area must have been under a green manure crop during the previous summer or alternatively lain fallow and compost at the rate of 5 tons per acre applied.

The subsidies mentioned earlier in this paper are increased by an additional 16 2/3 per cent of the farms concerned are included in an intensive conservation area, i.e. an area where the majority of the farmers have voluntarily agreed to protect all their available land and adopt sound farming methods suitable for their areas as approved by the Board. A committee of farmers is appointed to control the area and ensure that these approved practices are adopted by all farms within the area.

The additional 16 2/3 per cent subsidy is available to the Committee for administrative expenses or for the adoption of measures which will be of general benefit to the whole area.

Dr H. C. Trumble

The use of land and its conservation in Australia hinge essentially about water as a primary controlling factor. Comparatively little is available for the construction of further national schemes of irrigation, but more effective use could be made of existing storages and of the rainfall *per se*.

Approximately 50 million acre feet of natural rainfall per annum, on the average, have not so far been utilized for production from the soil owing to low natural fertility or the persistence of almost valueless native forest.

Average rainfall figures mean little apart from their indicator value. The probable frequencies of drought and flood risks, current losses from the soil by run off and evaporation and means of minimizing them require to be determined with statistical accuracy and agricultural applicability.

The Australian continent, for purposes of generalized land use may be divided into (*a*) the uncleared portion of highest rainfall, which extends

through both the temperate and sub-tropical coastal regions, (*b*) agricultural and pastoral lands that have supported most of the crops and stock raised, and much of which now shows evidence of water erosion and depleted soil fertility, (*c*) marginal crop lands characterized by both wind erosion and lowered fertility, and (*d*) extensive areas of semi-desert scrub, much of it shrub-steppe, which has suffered from exploitative grazing.

The various States have tended to develop separate services in their attempts to cope with the main problems of soil conservation ; recently a Standing Committee on Soil Conservation, with three representatives of the Commonwealth and six from the soil conservation services of the several States, was created.

Technical and scientific work falls into the categories of survey, research and education.

Erosion surveys have been undertaken, so far on a somewhat limited scale, by the Soils Division of C.S.I.R. in conjunction with State departments.

Researches on (*a*) the economic use of water resources, (*b*) the provision of vegetative cover capable of soil protection linked with increased production, and (*c*) the grazing management of pastoral lands need to be intensified. Additional herbage plants are required from overseas sources ; numerous technical factors associated with the use of alternative farming systems and new methods of improving soil fertility would repay study.

There is room for extended education concerning the principles governing soil conservation, especially among the younger people.

SOIL EROSION AND CONSERVATION PROBLEMS IN NEW ZEALAND

By D. A. Campbell, B.Sc., M.Agr.Sc.

SOIL EROSION

Increasing attention is being focussed on the problems of soil erosion and conservation in New Zealand so emphatic is the evidence of slip-scarred hillsides, sheet eroded slopes and uplands, recurrent flooding and its toll of damage and suffering.

The dominant features of the landscape—steepness, softness of the rocks, swiftly flowing rivers, variable and high-intensity rainfall, prevalence of wind and the strong contrast between induced and indigenous vegetation—assist in placing in perspective the susceptibility of the country generally to soil erosion. New Zealand is essentially a long narrow country with a backbone of rugged mountains (6,000–12,000 ft.) of immature topography flanked by large alluvial fans created by several steeply graded rivers.

The generally thin soils of the hill country are derived in the main from shattered sedimentary rocks that vary from hard, indurated greywacke of the axial ranges to very soft erodable mudstones and claystones of the east coast North Island and the friable volcanic ash of central North Island. When exposed these soils, over half of which are on steep country (over 35° slope), erode very readily.

The rainfall (25–40 inches) of the east coast of both islands is variable and torrential rains often follow periods of drought. The rainfall (40–100 inches) over the rest of New Zealand is fairly well distributed although very heavy falls are common. The type of rainfall and the regular winds, particularly on the high country, are conducive to active soil erosion.

The physical features were matched by a vigorous vegetation of several forest types, scrub, fern, tussock grass and swamp—infinitely varied and adapted to diverse micro-habitats. The tremendous change involved in replacing these with a small range of grasses has had a big influence on the stability of catchment areas and the regimen of rivers.

Soil erosion becomes a major problem in land utilization owing to its widespread occurrence. Sheet erosion by wind or water, and by both, has seriously affected the excessively grazed and burnt areas of tussock grassland particularly in Central Otago and on the high country of the South Island. It has also affected much of the cultivated lands of more gentle slope in both islands and the rolling to steep grasslands of the North Island.

Slip erosion is widespread on the steep farmed land of the North Island

while the softer and fractured rocks slump and flow readily, particularly the east coast areas.

Gullying is commonly associated with the types of erosion mentioned and assumes spectacular proportions on soft mudstone and shale slopes of the east coast of North Island.

The increased surface run off and the greatly increased supply of debris to streams has resulted in rapid filling of river beds, active lateral scour of their banks and increased spill-over of flood water and debris on to highly productive lowlands.

CAUSES

The introduced elements that have upset the stability of landscapes, hitherto in equilibrium, can all be regarded as farm management factors, and their impact on the native vegetation that held the balance between climate, soil and slope in various habitats is very significant. Farm management has operated chiefly through clearing and felling, burning, grazing and tramping, cultivation and drainage, while the severity with which some of these were applied was governed by the economic and social aspects of management.

Individually and collectively clearing, burning, grazing and cultivation have caused a decline in fertility and ultimate depletion of the vegetation, and can be regarded as predisposing causes of soil erosion.

These management factors influence soil structure, organic matter status, infiltration rate and other soil characteristics detrimentally, with the result that the soil is compacted, surface run off is increased, and the soil is exposed to the active agents of soil erosion.

Superimposed on this cycle of disintegration and accelerated erosion abnormal edaphic features such as torrential rain, very soft rocks, steep slopes and earthquakes accentuate the rate at which soil erosion proceeds in certain districts.

CONSERVATION

Comparative measurements of the influence of the various causative agents of soil erosion interpreted in the light of the history of land use of particular areas, together with information from re-vegetation trials and farming experience, provide a basis for consideration of conservation measures. April–August 1945: *N.Z. J. Sci. Tech.*

In essence, conservation problems centre round adequate vegetation to hold and protect the soil, and mechanical aids for farm land and river control.

On unfarmed land it is urgent to maintain vigorous natural vegetation, but this can be assured only by adequate safeguards against fire and grazing by wild animals—deer, goats, pigs, rabbits and opossums. Control of these animals is quite a serious problem. So often these areas are found in the headwaters of major rivers where high altitude rainfall, wind and frost make growth conditions uncongenial. There is encouraging evidence

of the capacity of native plants to regenerate and spread over damaged areas. In fact the reversion of millions of acres of marginal land to bracken fern, manuka scrub, and second growth forest has caused the virtual abandonment of large tracts of difficult country, while on poor eroded land invasion by the native Danthonia grasses has prevented much serious loss by erosion.

The major problem on farmed land is the necessary compromise between production and permanence which demands modification in land use often beyond the resources of those who farm the land affected.

Adequately protective pastures for hill country have not been evolved to date in New Zealand. There is evidence to prove that great improvement in hill country pastures can be achieved by using improved strains of grasses including possibly some of the native grasses, by top-dressing with lime and phosphate, by introducing clovers, by spelling and moderate grazing, by using a higher ratio of cattle to sheep, by adequate fencing and water supply, by creating reserves of fodder for periods of scarcity, and by shelter belts and blocks of trees on steep slopes.

Rotational grazing and spelling, control of rabbits, goats and deer, avoidance of overgrazing and of burning are measures, the adoption of which is desirable on the native high country grasslands in New Zealand.

There is not sufficient information to decide the maximum degree of steepness that may be cultivated safely, while there are no basic data to define the zone of permanent pastures or the effect of spaced trees in holding slopes too unstable to be held by grass alone.

Likewise there is but little known of ways and means to expedite regeneration of useful native forests. Extensive plantations of exotic trees were made by the early settlers for shelter and timber and for the control of wind erosion and the protection of stream banks.

Much remains to be done to determine further uses for native and exotic trees for farm forestry, including spaced planting on grassed hillsides. Some species of willows and poplars already indicate their ability to stabilize gullied earthflows and large slumps and are widely used in river control projects.

Conservation tillage practices used overseas have not been adopted as yet in New Zealand but this is in part due to the use of long crop rotations which include permanent top-dressed pasture that does much to develop structure resistant to erosion during the subsequent period of cultivation. However, soil saving techniques are badly needed on the continuously cultivated sloping land.

On ploughed and sown permanent grasslands modern pasture management has prevented soil erosion on all but the steeper slopes.

Since 1910 the Public Works Department and various River Boards have done much to control flooding and erosion of fertile bottom lands. The ever-growing demands for river control works and the high incidence of flooding and soil erosion on various catchments led to the passing of the Soil Conservation and Rivers Control Act in 1941.

The Council set up to administer the Act made an appraisal of the position in New Zealand and set up local authorities known as Catchment Boards to administer the Act in specific natural regions embracing the entire catchments of one or more rivers. To date eleven Boards have

been set up in the most troublesome areas, that collectively embrace 42 per cent of New Zealand.

The Council has instigated Educational publicity work using publications, filmstrips and talkie films, and is arranging for demonstrations and experimental work to be done on acquired land and in co-operation with farmers. Urgent river control works that safeguard productive lowlands are being generously subsidized by the Council in the various catchment districts.

SOIL EROSION AND SOIL CONSERVATION IN THE COLONIAL EMPIRE

COLONIAL OFFICE MEMORANDUM

In the Colonial Empire, within the past decade, there has been a marked increase in the general awareness of the dangers due to soil erosion, especially in areas where population increases have been substantial, and in many places considerable progress has occurred in the application of soil-conservation measures.

In 1937 an article by Sir Frank Stockdale drew attention to the position in regard to soil erosion in the Colonies and since then interest has been stimulated by the actions of successive Secretaries of State for the Colonies who repeatedly reminded Colonial Governments of the seriousness of the problem.

In 1938, Lord Harlech addressed a circular dispatch to Colonial Governors in which attention was invited to the question and the importance of according to soil-conservation measures a prominent and permanent place in the policies of Colonial Governments, was stressed.

Particular emphasis was laid on the point that such measures should not be regarded as purely the concern of the specialist departments of governments but as a matter of major policy having a direct bearing on the welfare of the communities. Furthermore, the provision of grants from the Colonial Development and Welfare Fund was contemplated in order to assist governments whose resources were inadequate to bear the costs of conservation projects.

Thus, soil conservation has been under constant and continuous review and, notwithstanding the hampering events of the war and its demands for manpower, interest has markedly increased and steady progress has been made.

Probably the most important advance has been the growth in popular appreciation of the dangers inherent in erosion and the need for active steps to conserve the soil. This growth has affected the less developed sections of the colonial communities just as much as the more developed peoples for, in parts of Africa, there is now considerable and increasing erosion consciousness among the native tribes.

Coupled with this growth there has been an increase in the appreciation that conservation practices should not be regarded merely as remedial measures undertaken to counteract a specific danger, but that the need is for the evolution of systems of husbandry that will maintain and enhance the natural fertility of the land in which measures to ensure the conservation of the soil find their appropriate place. Thus, in large parts of Africa, there is increasing need for the development of intensive systems of farming to replace the methods of shifting cultivation and extensive ranching which have hitherto been widely prevalent and which, under the stress of

increasing population can no longer suffice to maintain, let alone to raise, the level of subsistence.

Obviously, no one system of husbandry can be universally applicable ; modifications to meet varying conditions of soil and climate are necessary and these again must vary to suit the needs and ways of life of the cultivators and pastoralists themselves. In each locality, therefore, the primary necessity is to ascertain by experiment the systems best adapted to the conditions and thereafter to secure its adoption by cultivators by precept, example and, if need be, by a measure of compulsion.

Much progress has been achieved in devising systems of mixed farming suited to varying conditions in which both crops and live-stock play their part and by incorporating therein methods designed to counteract the dangers of erosion. Advances are not necessarily correlated with the gravity of the problem ; for example, erosion is a grave menace both in East Africa and in parts of the West Indies, but for some time past the degree of awareness of the danger and progress with counteractive measures have been much greater in the former region than in the latter, although in the West Indies apprehension of the position has increased of late years.

It may be generally stated that sheet erosion is the most widely prevalent orm of erosion, but in some places extensive gullying also occurs, whilst in drier areas wind erosion is a serious menace. The chief contributory causes have been excessive deforestation, cultivation of lands which by reason of their steep slope should not have been opened for cultivation at all, unsuitable methods of cultivation, lack of provision for dealing with surplus run-off of rainfall, the growth of crops conducive to erosion without adequate cultural safeguards, indiscriminate bush burning, lack of protection from wind and excessive concentrations of live-stock, especially during dry periods, leading to overtrampling and consequent soil loss.

The measures adopted to counteract erosion naturally vary to some extent according to conditions but they may be classified as (*a*) agricultural, (*b*) forestry and (*c*) engineering. Under (*a*) are comprised contour ploughing and planting, rotational strip cropping, the use of grass strips and live wash stops, the making of contour drains and wash stops, the planting of windbreaks to check wind erosion, restriction on the cultivation of those crops especially conducive to erosion, the use of cover crops and mulches, the control of grass and bush burning and the improvement of pastures, combined with the introduction of rotational grazing and, where necessary, the reduction of stock. Under (*b*) are comprised the establishment of forest reserves and the closure to cultivation of threatened areas coupled with their reafforestation ; such areas may include hill tops, steeply sloping lands, gullies and river catchment areas. An ancillary activity is the establishment of plantations of suitable trees for the provision of fuel and timber supplies for the use of populations. Under (*c*) are comprised the construction of contour bunds and terraces, the construction of stops and dams for the checking of gully erosion and the construction of works to deal with excessive run-off, as well as the maintenance of road-side drainage, neglect of which is often a source of gullying. With this is combined the provision of additional water supplies for live-stock and human consumption, thereby reducing excessive concentrations of live-stock during dry seasons and its attendant overtrampling and erosion and the

reclamation of swampy areas by drainage, thereby increasing the land area available for cultivation in situations least liable to erosion.

Experience tends to show that so far as is practicable it is good policy to reduce to a minimum any works for the direct control of erosion which have the character of major engineering operations and to replace them wherever possible by operations carried out by the cultivators themselves, since it has been found that, where such works are carried out by direct government agency in the first instance, it is difficult to arouse the interest of native cultivators and to induce them to assume responsibility for their subsequent maintenance.

The position in regard to soil erosion control in some of the various countries is briefly outlined in the following paragraphs.

In Kenya, a special Soil-Conservation Branch of the Department of Agriculture was instituted in 1938 to perform advisory and experimental work and to supervise and carry out conservation schemes, and in 1940 the Land and Water Preservation Ordinance and Rules gave wide powers for the protection of the resources of the country. In addition, the Control of Grass-burning Ordinance was enacted in 1941 with the object of lessening the effects of grass burning on erosion.

The measures taken under the Soil-Conservation Brancn included (1) the reclamation of eroded areas, (2) the preservation of water courses and water supplies, (3) afforestation, (4) the protection of good lands. The primary aim is, however, to achieve conservation by a sound system of mixed farming in all areas suitable for this type of agriculture. In 1941, for the protection of good lands against erosion, hundreds of miles of broad and narrow base terraces were constructed in European as well as in native areas, contour lines were set out in many thousands of acres, wash stops were fixed in many gullies, live wash stops, contours, banks and grass were planted on eroding lands and eroded hillsides were closed to grazing and to cultivation ; river and stream banks were protected and trees planted at the heads of valleys, etc. In addition, surveys of agricultural and living conditions in native areas were initiated to provide data for longer range planning.

In Uganda, a Development and Welfare Committee was set up in 1940 to work out an anti-erosion policy which laid down the following broad lines of attack.

(*a*) Prevention of the extension of semi-desert conditions in the north-eastern areas of the Protectorate to the agricultural and pastoral areas in the south.

(*b*) The counteraction of the effects of overstocking in grazing areas by the organization of rotational grazing, the provision of additional water supplies for stock, and the establishment of cattle markets for the sale of surplus stock.

(*c*) The development of a more rational land-utilization policy, aimed at removing from arable cultivation, areas unsuited thereto and planting in trees for the provision of village timber supplies.

(*d*) The evolution of a sound system of cropping which ensures the restoration and preservation of the crumb structure of the soil and the maintenance and enhancement of soil fertility.

(*e*) The institution of Crown and Native Administration Forest Reserves.

Much headway has been made in carrying out the policy outlined, including the demarcation of grazing areas which has led to a simple form of rotational grazing which has been widely adopted and in which the Native Administration has co-operated heartily. Dams, impounding reservoirs and boreholes, have given improved village water supplies; stock markets for the sale of surplus stock in dangerous areas were established which led to greatly increased sales of cattle (42,000 in 1938 to 130,000 in 1942) and achieved a definite and important change in the native outlook which now has more regard to quality and the monetary value of cattle than formerly.

In 1941 the areas of Crown Forests increased by 380 square miles; early controlled burning was carried out over 1,500 square miles; fuel reserves and windbreaks were materially increased; strip cropping has been widely adopted; stall feeding of stock has been encouraged in thickly populated areas with a view to the use of cattle manure; live strip wash lines were planted in thousands of plots; many hundreds of gullies were stopped; areas have been selected for intensive demonstrations in rural reconstruction. Vigorous propaganda directed to the spread of information as to the dangers of erosion and means of counteracting it have been initiated and it can be said that there has been a very general awakening of public opinion to the danger of soil erosion so that control measures are being actively prosecuted despite the difficulties arising out of the war.

In Tanganyika, in 1938, instructions were issued indicating that the adoption of planned measures for the control of erosion was an integral part of the Government's policy but before that date Native Authority Rules in most districts enforced soil-conservation measures.

Despite the war satisfactory advances were made in measures which included contour banking and ridging contour hedges, windbreaks, demarcation and protection of hill tops, river banks, steep slopes; gully washtops, provision of additional water supplies, establishment of forests, amelioration of soils by mixed farming and manuring, and reduction of live-stock in overstocked areas.

Native administration has greatly assisted with communal labour for works, by injunctions, etc., and teams of native instructors have been effective in organizing continuous work on conservation. By 1942, considerable areas had been protected in some degree by contour ridges, broad based terraces, live contour hedges, the planting of elephant grass, sisal, etc., in gullies, etc., and 1,200 hill tops were closed to cultivation while 215,000 acres were declared as additional forest reserves.

Many dams of varying sizes had been constructed for the provision of water supplies for stock, farming standards had shown some improvement, the use of cattle manure had extended and marked progress had been made in schemes for the marketing of surplus cattle, sales of native owned stock having reached 250,000 annually and it was considered that the problem of soil erosion control was well understood and that progress was satisfactory.

In Northern Rhodesia, active measures for checking soil erosion have mainly been confined to the maize belt of the Southern Province where several large European farms have been contour ridged and this form of protection, as well as grass strips, is becoming of increasing interest. The introduction of a four-course rotation, the use of manure in place of

continuous maize cropping and the adoption of improved farming methods are steadily spreading and should do much to halt soil impoverishment. In other areas, efforts are in operation to effect a change from the traditional mound cultivation to contour ridge cultivation with the additional protection of storm drains constructed at suitable intervals.

In Nyasaland in 1937 a Soil-Conservation Officer was appointed and early measures of conservation included early burning in the control of bush fires, the preservation of natural vegetation on stream banks and steep slopes, contour ridge cultivation in place of mounds, the construction of silt pits, drains, banks, vegetation belts, etc., to hold up excess run-off, rotational cropping and grazing and the use of manures. In 1940 a free grant of £16,500 was provided towards anti-erosion measures and a general change over to ridge cultivation soon became evident as well as strip cropping and periodic pasturing. Selected areas were studied since 1941 and two Soil-Conservation Officers were appointed in 1942.

Over 5,000 village forest reserves were established under the control of village headmen and a policy of gradual de-stocking of those areas where overstocking was dangerous, was instituted.

In Somaliland, where 90 per cent of the people are pastoralists, a survey was made in 1942 of the grazing areas and recommendations, designed to ameliorate conditions, were drawn up for consideration in the hope that a general grazing plan may be formulated.

In Zanzibar, where the principal crops are tree crops, soil erosion is not an acute problem, but in 1940 the construction of contour terraces and the planting of trees and grasses was begun with promising results and strip cropping is being encouraged.

In Basutoland in 1935 the urgent need for amelioration of soil erosion conditions was stressed by a Commission and as a result £160,000 was made available in 1936 for control works under the Colonial Development Act.

The main problem was the control of run-off of storm water from overgrazed sloping areas and the education of native opinion to appreciate the need for necessary and varied soil protective measures which a Soil-Conservation Section of the Department of Agriculture was formed to implement. In addition, improved methods of agriculture, based on mixed farming, were demonstrated, while the use of trees for fuel as well as for soil protection purposes was stressed in order to enable cattle manure to be returned to the land. In rich soils, grass strips proved efficient and economic in checking sheet erosion while in light or sandy soils contour banks were most satisfactory in checking gully erosion.

By 1942, 100,000 acres of eroded land had been efficiently dealt with, a tree planting programme laid down aiming at the planting of 2,000,000 trees annually and a conservation policy had been given a legal basis under Native administration.

Sheet and gully erosion in Bechuanaland are mainly due to overstocking in the neighbourhood of water supplies so that the principal measure of control is the provision of additional water supplies and towards this purpose £139,000 was made available in 1939 from the Colonial Development Fund. By the end of 1940, 142 water supplies were completed and the resulting progressive dispersion of stock from overcrowded areas proved

beneficial in saving the soil. The prevention of bush fires was also given attention as well as a study of trees most suitable for providing protection against soil erosion and the provision of timber for fuel and building purposes.

In Swaziland, overstocking of cattle in certain areas, concentration of cattle at certain dipping tanks and unsatisfactory cultural practices are the main causes of erosion. In 1938 the Colonial Development Fund granted £21,000 for the construction of 50 additional dipping tanks and the provision of additional water supplies. Also contour grass strips were demonstrated and with much propaganda have been widely introduced into native areas with good results.

In the Gold Coast the main causes of erosion are shifting cultivation, uncontrolled grazing and annual grass fires. Since 1938, Native Authorities have issued orders in certain areas prohibiting the cutting down of forest for new plantations and controlling grass burning while over a million shade trees have been issued to farmers in cocoa areas. Though no large scale measures had been taken up to 1942 for initiating soil-conservation works, data were being collected towards that aim, for use after the war period.

In Nigeria, soil degradation and erosion are taking place over much of the savannah country in the north and also in the more densely populated areas in the south. Considerable work has been done by the Department of Agriculture in improving agricultural methods and extending agriculture to marshy lands thus relieving the uplands, and by the Forest Department in the establishment of forest reserves and their protection from burning, while the Public Works Department and other Departments are co-operating in general soil-conservation measures including the planting of shelter belts in the dry zones to counteract wind action, grass strips, economic trees, etc. Anti-erosion work is, however, still largely in the experimental stage, but useful knowledge is being compiled for application as soon as circumstances permit.

In Sierra Leone a pernicious system of shifting cultivation has degraded the soil in the upland regions and therefore efforts are in progress to encourage the cultivation of river flats and valley bottoms so that denuded upland areas may be protected and relieved from the pressure of demand for farming lands. Towards these ends rice experimentation was initiated on tidal flats in 1938; in 1940 an Irrigation Engineer was appointed and preliminary surveys showed considerable areas of swampy lands to be available for reclamation; in 1942, £303,000 was approved under Colonial Development and Welfare Act for the development of 50,000 acres. Good progress was reported and it may be accepted that the seriousness of the problem is fully realized and measures are in operation to counteract the evils of erosion.

In Ceylon the seriousness of soil erosion has been recognized for many years and the introduction of ground covers, of contoured drainage, and of terraces in the tea, rubber and coconut estates has been highly beneficial. In 1939, a Soil-Conservation Board was formed and considerable progress has been made in the adoption of protective measures.

In Malaya the position is largely similar to that in Ceylon and clean weeding on rubber estates has widely given place to cover cropping, contour

bunding and silt pitting with good results. In small holdings the position has never been serious.

The erosion and gullying formerly due to tin mining activities have now largely been eliminated by strict control measures. In opening up tea estates on the hills, the experience of Ceylon has been fully applied and in pineapple culture in the lowlands experimental work with a view to the control of erosion by economic methods was in progress.

In rice and coconut areas erosion has never been serious and on oil palm estates, normal precautions are now the rule. In 1939 a standing Central Committee was appointed to investigate and advise on the problem, and evidence showed that the position had considerably improved in recent years.

In Mauritius soil erosion is not a serious problem owing to the nature of the main cultivations and the effective existing protection of the forests and river margins.

In Cyprus, the need for soil conservation has long been recognized and the art of terrace making is traditional amongst cultivators. Nevertheless, removal of forest and excessive grazing cause severe erosion in some areas so that attention has been given to reafforestation for which in 1941 £210,000 was granted from the Colonial Development and Welfare Fund while legislation has been enacted to control grazing especially in forest areas, with excellent results. As a result of demonstrations in soil erosion control methods, farmers are now taking anti-erosion measures on their own lands.

In Palestine, the wasteful practices of haphazard cultivation and extensive grazing have led to extensive soil denudation. In 1940, a Soil-Conservation Board was set up and revealed the need for legislation to control erosion which led to the Flooding and Soil Erosion (Prevention) Ordinance in 1941 giving control of special areas for the application of anti-erosion measures. Attention was also given to the control and utilization of sand dunes, the demonstration of terracing, the formation of a grazing policy, the planting of windbreaks and to propaganda designed to stimulate interest in soil conservation.

In Trans-Jordan, soil erosion is widespread due to deforestation, over grazing, faulty methods of cultivation and failure of peasants to maintain the ancient terraces. The urgent demand for land has impressed farmers with the need for erosion control measures and these are mainly based on afforestation combined with terracing and contour cultivation.

In the British West Indies the gravity of the position varies considerably in different dependencies. In some areas erosion is serious and considerable efforts have been made to devise an agricultural policy designed to increase crop yields and assist in conservation of natural resources, and as a part of that policy, soil-conservation measures are advocated. In consequence, there has been a considerable increase in public awareness of the need to safeguard the land for the future.

Soil erosion is not a serious problem in the Bahamas, Bermuda, Barbados, British Guiana or British Honduras.

In Jamaica, the Leewards, the Windwards and Trinidad erosion is serious in varying degrees.

The rapidly increasing population in Jamaica, where much of the cultivated land is steep, has compelled attention to the need for soil-

conservation measures and propaganda and demonstrations of methods have aroused interest so that progress in their general application is expected, though much investigation still remains to be done to evolve the most suitable methods to apply to the different types of soil.

In most parts of these dependencies demonstrations are in progress as to the best methods of soil erosion control to apply to suit the varying ecological circumstances found in the different areas, reafforestation being a promising method as well as general cultural methods (contour ploughing, banking, terracing, draining, grass bunding and strip cultivation) and improved cultural methods based on mixed farming, silt pitting, etc.

Programmes of soil-conservation works, planned for most of the West Indian Islands, are financed by the Colonial Development and Welfare Fund and long range research has also been planned.

In Fiji little damage by soil erosion occurs on the flat alluvial lands but sheet erosion is common on undulating areas due to faulty cultural methods, bush fires, and some overstocking in the dry zones. Demonstrations of protective methods are in progress and legislation has been enacted to control indiscriminate burning and to enforce reasonable attention to measures designed to conserve the soil.

Although soil erosion remains one of the chief agricultural problems in the Colonial Empire, it is remarkable that, despite the incidence of war, popular appreciation of its serious nature has greatly increased and there is little doubt that the future will see substantial and general advances in the application of soil-conservation measures.

These notes are compiled from ' Soil Erosion and Soil Conservation in the Colonial Empire ' by Tempany, Roddan and Lord—*Empire Journal of Experimental Science*, Vol. XII, No. 47, July 1944, as giving the latest information on the subject.

LAND UTILIZATION AND CONSERVATION IN CANADA

By C. C. Coutts and Dr E. S. Hopkins

LAND AREAS

The subject of land utilization and conservation in Canada has received attention by the Government of Canada, especially since the establishment of the Prairie Farmers Rehabilitation Act (P.F.R.A.) in 1935. Canada, which played such an important rôle during the war, is perhaps being regarded as becoming one of the leading nations of the post-war world. Certainly Canada is being expected to provide an important share of the agricultural products for the starving millions in Europe and Asia. People unacquainted with the geography of Canada are frequently of the impression that its possibilities of agricultural development are endless. This impression is understandable when it is considered that the area of the Dominion of Canada is 3,695,189 square miles, as compared to 3,735,209 for the United States and its dependent territories, and 3,776,700 for the total area of all Europe (1). The area of Canada is over 28 per cent of the total for the British Empire (2). However, when the area of some of the geographical features, which are unsuitable for agriculture, are taken into consideration there is not as much available farming land as would at first appear. The following table gives the areas of the main political divisions as well as some of the main physical features of Canada.

Table 1

Land areas of principal political divisions and main physical features of Canada

political divisions and physical features	area (square miles)
total area of Canada	3,695,189 (*a*)
area of fresh water	228,307 (*a*)
area of nine provinces	2,003,319 (*a*)
area of Yukon and North-west Territories	1,463,563 (*a*)
area of Cordilleron Mountain System	530,000 (*b*)
area of Tundra	1,002,494 (*c*)
area of Precambrian or Canadian Shield	1,825,000 (*d*)
area of organic soils	20,313 (*e*)

(*a*) *Canada Year Book*, 1945, p. 1.
(*b*) *Canada Year Book*, 1945, p. 6.
(*c*) Estimation.
(*d*) Prof. Moore, 'Elementary Geology for Canada.'
(*e*) Estimation.

The area of the Cordilleron Mountain System is given at 530,000 square miles, most of which is unsuitable for agricultural work although it contains some very highly productive tracts of land. The area of the Precambrian Shield, as shown in table 1, has been estimated at 1,825,000 square miles, or approximately one-half the area of Canada. Within this shield, however, there is quite a large clay belt in Ontario and Quebec. In Ontario this has been estimated at 20,313 square miles (3), but for Quebec no figures are available. The area of Tundra in Canada, that is all land north of the tree line, is estimated at 1,000,000 square miles. It can readily be seen from these figures that in spite of the large total area of Canada, the area suitable for agriculture is comparatively small.

ACREAGES IN FARMS

Total acreages in farmland, pasture crop and summerfallow

After considering some of the main geographical features of Canada and the amount of land that is unsuitable for agriculture, it may be of interest to examine the acreages in occupied farm land, pasture, crop and summerfallow. Table 2 gives this information according to provinces as reported in the 1941 census.

Table 2

Acreages in farmland, pasture, crop and summerfallow in Canada

province	area of occupied farmland (acres)	area of improved pasture land (acres)	area of unimproved pasture land (acres)	area under crop (acres)	area of summer-fallow (acres)
Canada . .	173,563,282	8,502,873	52,378,236	56,279,910	23,535,106
Prince Edward Is.	1,168,868	237,062	80,604	470,351	3,934
Nova Scotia .	3,816,646	175,236	731,801	575,934	3,748
New Brunswick	3,964,109	296,776	364,493	865,914	8,472
Quebec . .	18,062,564	2,519,354	2,090,823	6,137,521	6,776
Ontario . .	22,387,981	3,237,865	3,879,182	9,261,626	320,765
Manitoba .	16,891,322	455,487	4,823,515	6,327,967	2,767,335
Saskatchewan .	59,960,927	783,991	19,815,940	19,767,341	13,803,088
Alberta . .	43,277,295	625,578	18,745,520	12,284,123	6,545,931
British Columbia	4,033,570	171,614	1,846,358	589,133	75,048

The total area of occupied farmland in Canada, according to the 1941 census, was 173,563,282 acres, or 271,192 square miles, which is less than 8 per cent of the total land area. The area in crop, summerfallow, improved pasture is 88,317,889 acres, or about one-half the occupied farmland. Unimproved pasture land, located largely in the Prairie Provinces is only slightly less than the total area under crops. While sufficient data is not available to enable a reliable estimate to be made of the potential farmland in Canada, an approximate estimate might be given of 130,000,000

acres suitable for crop production or about 41,000,000 acres more than that now in crop, summerfallow and improved pasture. The area of occupied farmlands has steadily increased from 36,046,781 acres in 1871 to 173,563,282 acres in 1941.

Acreage trends

The area of most crops has increased steadily from 1891 or even from 1901 at which time data became available for all field crops. In some years there is a marked decrease in the acreage of certain crops while in others there may be a considerable increase. This variation is dependent on several factors such as cost of production, available labour, and especially the market price. Details in regard to trend of acreage of various crops may be found in appendix I.

FORESTRY

Forest areas (4)

The forested area of Canada is estimated at 1,220,400 square miles or 35 per cent of the total land area. Within the boundaries of the nine provinces the forested area totals 1,160,405 square miles or 58 per cent. About 450,000 square miles of the existing forests are classed as unproductive. They consist of small trees which cannot be expected to reach merchantable size because they are growing on poorly drained lands or at high altitudes or are subject to other adverse site conditions. These unproductive forests, however, perform valuable functions. They help to protect watersheds and conserve water supplies, they provide fuel and building materials to local residents and travellers in remote areas, and they are the habitat of valuable game and fur-bearing animals.

The productive forests, covering more than 770,000 square miles, are considered to be capable of producing continuous crops of timber suitable for domestic and industrial purposes. About 430,000 square miles of productive forests are considered to be accessible at the present time. The total stand of timber of merchantable size is estimated to be 389,000 million cubic feet, of which 239,000 is accessible. Expressed in commercial terms, the accessible timbers is made up of 252,000 million board feet of logs in trees large enough to produce saw logs and 1,685 million cords of smaller material suitable for pulpwood, fuel, posts, mining timbers, etc.

Kinds of trees (4)

In Canada there are 130 distinct species of trees. Only 33 of these are conifers or softwoods, but they comprise over three-quarters of the standing timber and supply 80 per cent of the wood used for all purposes Of the deciduous leaved trees only about a dozen are of commercial. importance as compared with twice that number of conifers. Details as to the forested land area in Canada may be found in appendix II.

Forest policy (5)

In ' The Wallace Report ' the outstanding problems of the forest policy are dealt with under twelve headings : forest management ; forest surveys and inventories ; protection of forests from fire, insects and fungi ; forest

research ; forestry education ; reforestation ; prairie tree planting ; colonization ; farm woodlots ; recreational forests ; municipal forests and forest legislation. Under the heading ' reforestation ' it is stated that in general success in forest management throughout Canada is founded upon natural regeneration. In situations where this fails to develop, recourse must be had to artificial restocking. In the more accessible areas where forests show depletion by fire, insects or other causes, reforestation should be undertaken when justified by the public interest.

SUB-MARGINAL FARMLAND

What may be classified as sub-marginal farmland, as is well known, is dependent upon a number of factors of which the yield, cost of production and market price of the particular crop grown are of primary importance. The problem of what to do with sub-marginal land has received little attention in Canada until recent years. The early immigrants settled along the St Lawrence River and the Great Lakes. Most of these people settled on land which was largely covered with trees and when cleared and broken produced fairly satisfactory crops in this humid region. Even to-day very little is being done in regard to the policy of sub-marginal land in Eastern Canada. However, each year soils specialists of the Department of Agriculture are surveying additional land and more attention is now being given to the type of land on which any new settlements are established.

When the Prairie Provinces of Canada were settled, people came from Eastern Canada, the United States and the British Isles and continental countries of Europe. Soil surveys were unknown at that time and as a result no thought was given to the type of land on which these people settled. For a few years some land produced fairly good crops, especially in years of normal or above normal precipitation, but it was soon found that some of it was unsuitable for grain production. The problem of sub-marginal land is now receiving more attention in the Prairie Provinces. Unsuitability for cultivation arises from one or more of several conditions, such as rough topography, excessive stoniness, alkali, light-textured soil with poor water-holding capacity and an inadequate supply of soil moisture on account of a light precipitation (6). Individual areas of sub-marginal land may vary in extent from a few acres to several hundred thousand acres.

An example of injudicious settlement on a large scale occurred in South-Eastern and East Central Alberta. Much of the settlement in this region occurred during good years which culminated in the bumper crop of 1915. Normal dry conditions in the year following 1917, however, forced most of the settlers to abandon their holdings. In 1923 the province of Alberta set up a Special Municipal Areas Board following investigations of conditions arising in Southern Alberta after the drought of 1919–1921. The removal of sub-marginal land from crop cultivation and the utilization of this land for grazing purposes is the function of the Special Areas Board. This board at the present time has over 8,000,000 acres of sub-marginal land under its control.

Following the disastrous drought and soil-drifting conditions which

commenced about 1930 and as a result of the injudicious settlement of large areas of the prairies with the accompanying evils of rural relief, losses from tax delinquency, led to the passing of the Dominion Prairie Farmers Rehabilitation Act in 1935 and under it a branch dealing with land utilization. The major objectives of this programme include the following :

(*a*) The permanent withdrawal of sub-marginal prairie land from cultivation.
(*b*) The development of such areas for grazing purposes.
(*c*) The resettlement on suitable farmland of farmers removed from sub-marginal areas.

In practice these objectives are being realized through the organization of P.F.R.A. community pastures, and through various settlement schemes, chiefly on new irrigation projects.

LAND RECLAMATION

Irrigation

Irrigation in Canada has been largely confined to the Provinces of Alberta, British Columbia and Saskatchewan. The Water Resources Office (7) under the Water Resources Act of Alberta deals with all matters affecting the control of water supply generally, as well as the inspection and authorization of works for the use of water for domestic, municipal, industrial, irrigation, water power and other purposes. The Irrigation Districts Act of Alberta provides for the formation of irrigation districts, and authorizes the raising of loans under by-laws adopted by voters of the district.

The area to which water could be delivered in 1943 by the thirteen major projects in Alberta was reported as 535,000 acres and the actual area irrigated as 399,000 acres. In addition 623 private schemes have an irrigable area of 70,700 acres. In British Columbia irrigation projects are on a much smaller scale than in Alberta. The irrigable area in 1941 was 68,469 acres, of which 44,560 acres were under irrigation in fifty-seven projects. In Saskatchewan nearly all the irrigation projects have been initiated by the P.F.R.A. There are approximately 63,820 irrigable acres, of which approximately 25,000 acres are being irrigated.

Drainage

Drainage is one of the most important factors in improving agricultural production in all Eastern Canada and the coastal areas of British Columbia. The Province of Ontario has been keenly interested in land drainage for many years and has in all five drainage acts which deal with the control and assistance by the government. They include assistance in main drainage channels as well as tile drainage on crop land. Economic conditions have retarded further drainage development in recent years, so much so that a large percentage of the ditching machines and tile factories were idle even before the war.

Dykeland

The marshlands of Nova Scotia and New Brunswick have an estimated acreage of dyked land of 80,000 acres (8). Decline in the livestock industry of the Maritimes and a much lower market price for hay has reduced the value of the marshlands to a point where the upkeep of the dykes became uneconomic. However with better prospects for the livestock industry the time has come when there is now good reason for rehabilitation of these marshlands. It has been proposed that the Dominion co-operate with the provinces concerned in this work as it is beyond the resources of the marshland users.

Land clearing

Some provinces have given material assistance in clearing land. In Quebec settlers established under the Gordon Scheme in the early 1930's were given assistance by way of premiums for land clearing and ploughing according to the Quebec Land Policy of 1933. The Quebec Government supplies heavy equipment at the present time for land clearing at a comparatively low rate. The Province of Saskatchewan in its Northern Settlement Re-establishment Policy has put in large power land clearing equipment to clear a certain acreage for each family.

SOIL EROSION CONTROL

Soil drifting

In Canada soil drifting occurs mainly in the dry areas of the Prairie Provinces. In these regions grain is grown largely in a short rotation with a considerable acreage of summerfallow but without any grass, hay or pasture. Under these conditions and especially on the lighter soils in regions with light precipitation soil drifting in very dry years is liable to become serious.

The Dominion Experimental Farms have undertaken many experiments in order to learn improved methods of controlling soil drifting. In some regions strip farming has been developed on an extensive scale. In this method wheat is grown in alternate strips with summerfallow, the strips being about 16 to 20 rods in width and running in a direction at right angles to the prevailing winds. Experiments have shown that surface tillage is equal to ploughing land in so far as yields per acre are concerned, that it is a less expensive operation and most important of all that by leaving the stubble and trash on the surface of the ground, soil drifting is very effectively checked.

Under very extreme conditions emergency tillage methods have been used such as listing and applying straw or manure on focal points. In some regions cover crops seeded in the face on the summerfallow are very helpful. On soil that is very susceptible to drifting it may be necessary to seed it permanently to grass, crested wheat grass (*agropyron cristatum*) being the most suitable.

Any one of the foregoing may provide adequate control, but generally a combination of methods is desirable. The choice of methods will depend upon the soil type and the region.

Water erosion

Water erosion is another type of erosion which is fast depleting the productivity of many Canadian soils. Although there are no figures available as to the amount of land affected by this type of erosion it is known that thousands of acres are damaged every year. Unlike wind erosion, which occurs mostly on the Prairie Provinces, the losses from water erosion are felt in all parts of Canada. Water erosion is most severe on sloping land which has been ploughed up and down the slope, in row crops grown on rolling land, and on summerfallow land. Following heavy rains both sheet and gully erosion may occur on a very small scale on sloping fields, and unless the necessary control measures are taken immediately, it may soon reach serious proportions. Gullying has become so serious in some areas that it interferes with the efficient use of machinery. The greatest loss from water erosion is caused by the carrying away of the rich top soil to areas where it becomes useless to agriculture.

In view of the serious losses caused to the productivity of the soils in many parts of Canada, the Dominion Department of Agriculture Committee on Reconstruction has suggested that soil conservation projects should be established in each of the Provinces of Canada with the first projects being located in areas where the most serious erosion has already taken place.

SOIL FERTILITY CONSERVATION

Types of agriculture and zoning possibilities

Various types of agriculture have developed throughout Canada dependent upon markets, climate and soil. Once economic considerations are met the feasibility of any type of agriculture will depend upon the climate and the soil. The decisive influence of climate and soil on the type of agriculture in Canada may be illustrated by the grazing and wheat types on the brown soils, wheat growing on the dark brown soils, and mixed farming and wheat growing on the black soils of the Prairie Provinces. In a similar way different areas across Canada are more favourable for the growth of certain crops than for others, and hence different types of agriculture have developed. With some of these different types of agriculture, different degrees of specialization may tend to decrease fertility levels.

As mixed farming is departed from the number of crops grown and the amount of livestock kept on any farm may become less. There may be a tendency to use land which is sub-marginal for certain crops. With increasing interest in certain crops there may be a trend for these crops to predominate in the rotation to such an extent that the fertility of the soil may be difficult to maintain. Thus, while different special types of agriculture may be a sound, economic short-term policy, on the basis of all factors involved, nevertheless soil fertility problems may increase. But since some soils are more suitable than others for some crops, the choice of a type of agriculture adapted to the soil may enable the farmer to maintain soil fertility more easily. Increased efficiency will provide larger net profits as a result of lower production costs, increased yields and quality of products.

Effect of high and low prices on use of commercial fertilizer

The sale of fertilizing materials and fertilizers in Canada increased from 166,407 tons in 1933 to 334,003 tons in 1939. By 1944 the sale of fertilizers had made another marked increase when 535,108 tons were sold. This represents an increase of 201,105 tons or 60 per cent during the first five years of the war.

The general rise in agricultural prices no doubt was largely responsible for the increased sale of fertilizers. However, a Dominion Government subsidy may also have had some influence during the last three years. The influence of agricultural prices on the use of fertilizers will vary with different commodities. Any trends in favour of the livestock industry will result in increased amounts of manure available for the soil. The present world shortage of human food would indicate a greater use of commercial fertilizers in an effort to increase production.

FUTURE AGRICULTURAL DEVELOPMENT

Decreasing percentage of farmers required

Agriculture has expanded in Canada for a long period of years and for a considerable time immigration was encouraged. During this period of expansion the total population increased from 2,436,297 in 1851 to 11,506,655 in 1943 (9). The greatest increase took place between 1891 and 1921 when the population increased by 3,954,710. In the early days Canada was essentially rural ; in 1851 there were 86·9 per cent of the population on farms or in small scattered communities. The building of railroads, accelerated industrial development and expansion of markets changed this picture, and by 1941, 6,252,416 people, or 54·3 per cent of the total population, were resident in incorporated cities, towns and villages. The farm population, which was 31·7 per cent of the total in 1931 declined to 27·5 per cent by 1941. The introduction oı the tractor and the improvement of farm machinery is making it possible for a decreasing number of farmers to operate a greatly increased acreage of land.

The agriculture of Canada is largely dependent upon its export trade. In a country of this size with its potential agricultural land it is readily realized why so much depends on export trade. It has been estimated by some that only about 40,000,000 acres are required to feed the 12,000,000 people in Canada, while others have estimated that only 2½ acres of arable land are needed to provide a human being with food, clothing and other necessities. However, at the present time Canada has 80,500,000 acres in crops and summerfallow.

URBAN POSSIBILITIES VERSUS DECENTRALIZING OF INDUSTRIES

During periods of high prices the city wage-earner lives in comparative comfort with a steady income. However, when prices drop and unemployment increases, many city people find themselves without any means of support. As a result many turn to the farm in an effort to eke out an existence. In recent years several projects have been organized for un-

employed men on the fringes of many Canadian cities. Such schemes have as their objective the provision of cheaper living to the urban worker. Some industrial concerns have sponsored home and garden properties for their employees.

In the opposite direction is the establishment of cottage industries such as canning, preserving, weaving, etc., in rural areas. This also has its advantages provided it is not expected to establish itself as a self-supporting industry. It tends to bring industry into the open country and farming into an urban framework. In March 1941 the Federal Government announced the appointment of a special Material and Human Resources Board to guide the wider distribution of industry in Canada.

Farm taxation

While the problem of taxation is not confined to the rural communities it is a very important problem. To appreciate the full significance of the increase in farm taxes as it affects the farmer, it is necessary to compare the index number of farm taxes with the index number of the price of farm products. A review of the Ontario farm taxes situation will give some idea of the situation (10). From 1906 to 1920 taxes lagged behind farm prices and were not particularly burdensome. Between 1920 and 1924, due to a sharp decline in prices, taxes became relatively higher. This relationship was changed somewhat in 1925 due to a rise in farm prices. During the period 1925 to 1929, taxes increased fairly rapidly while prices remained more or less constant. When prices of farm products dropped from 100·8 in 1929 to 48·4 in 1932, taxes failed to decrease accordingly, so that the relative burden to the rural tax-payer increased. Slightly higher prices beginning in 1935 accompanied by a further decrease in taxes showed the beginning of a gradual adjustment. During the war years taxes have again increased but there has also been an increase in the price of farm products. However, a decrease in the price of farm produce will again cause a burdensome load to the farmer.

Tenure

During the past twenty years there has been a marked change in the status of farm tenure. In 1921, 85·7 per cent of the farms were operated by owners. By 1931 this figure had dropped to 80·1 per cent and this downward trend continued so that by 1941 only 75 per cent of the farms in Canada were occupied and operated by owners. On the other hand, tenancy has increased, rising from 7·9 per cent in 1921 to 12·7 per cent in 1941. This, on the whole, is true for all the provinces. The most marked development of tenancy is on the Prairie Provinces. In Manitoba in 1941 only 66·1 per cent of the farms were occupied by owners, while in Saskatchewan only 53·0 per cent and in Alberta 62·8 per cent.

Saskatchewan in 1941 had the highest percentage of farms operated by tenants, namely 24·3 per cent. Manitoba with 18·8 per cent was in second place and Alberta with 16·9 per cent was third. Of the Eastern provinces, Ontario was highest, reporting 11·89 per cent and Prince Edward Island least with only 2·44 per cent of its farms being operated by tenants.

In 1921 there were 6·6 per cent of the farms in Canada operated by part owners and part tenants, that is owners renting additional land. In 1931 this group was increased to 9·3 per cent, while in 1941 it was further increased to 11·57 per cent. Over the past twenty years the farms operated by managers have never reached 1 per cent of the total number of farms in Canada.

Continuous investigations required in interests of farmers

The future of Canada is dependent to a large extent on the success of its agriculture. Agriculture should produce an adequate supply of food at reasonable prices and at the same time provide a market for urban industries. To achieve this condition farmers must be supplied with the best possible agricultural information. This advanced knowledge can be secured only from continuous, well-organized scientific research. The Dominion Experimental Farms and other scientific institutions engaged in agricultural research in Canada provide information which promotes the improvement of the practice of farming. They show how land may be utilized to the best advantage and how the soil may be conserved for permanent use.

REFERENCES

(1) *The Canada Year Book*, 1945, 1.
(2) *The Canada Year Book*, 1934–1935, 165.
(3) Hills, G.A., 'An Approach to Land Settlement Problems in Ontario,' *Scientific Agriculture*, December, 1942.
(4) *The Canada Year Book*, 1945, 247.
(5) *The Wallace Report*, 'Let us Look at the Forests,' 1943.
(6) Canadian Department of Agriculture, P.F.R.A. '*A Record of Achievement*, 1943.'
(7) *The Canada Year Book*, 1945, 245.
(8) *Reconstruction Projects on Soil Conservation*, December 1943.
(9) *The Economic Annalist*, **13**, 60–61, November 1943.
(10) Hudson, S. C., 'Taxation in Rural Ontario,' *Technical Bull.*, **4**, March 1936.
(11) *The Economic Annalist*, **13**, 61, November 1943.

APPENDIX I.

(Decennial Census)

CROP ACREAGES IN CANADA, 1871–1941

	1941	1931	1921	1911	1901	1891	1881	1871
wheat	21,882,000	26,355,136	17,835,734	8,864,514	4,224,542	2,701,213	2,366,554	1,646,781
oats	12,266,000	12,837,736	13,879,257	8,656,179	5,367,665	3,961,356		
barley	5,304,000	3,791,395	2,043,669	1,283,094	871,800	868,464		
rye	959,908	799,335	1,842,498	131,240	176,679			
peas	64,410	81,567	192,749	294,750	670,320			
beans	121,842	86,073	62,479	52,869	46,634			
buckwheat	222,365	335,807	360,758	371,560	261,726			
mixed grain	1,478,549	1,195,625	861,136	525,224	273,490			
flax	997,984	648,100	533,147	878,872	23,086			
shelled corn	340,964	134,991	296,866	321,875	360,758			
potatoes	507,000	591,804	534,621	464,405	448,743	450,190	464,289	403,102
roots	128,370	138,711	227,675	207,861	205,160	148,143		
hay and clover	9,559,000	9,114,457	8,678,883	8,289,407	6,543,423	5,931,548	4,458,349	3,650,419
alfalfa	1,149,000	306,000	263,892	96,890				
fodder corn	419,345	335,291	585,395	293,775				
grain hay	555,014	699,731	57,603					
sugar beets	58,252	42,589	28,367	20,677				
tobacco	74,425	58,329	16,628	25,826	11,906			
summerfallow	23,535,106	17,007,346	*12,000,991	2,538,009				
total	79,623,534	74,560,023	60,302,348	33,317,027	19,485,932	14,060,450	7,289,192	5,700,302

Note.—The acreage statistics of all crops were not collected by the decennial census until 1900.

* Includes idle land in 1941.

CLASSIFICATION OF FOREST AND OTHER LAND

province or territory	forested land				non-forested land		total area		
			total forested land						
	productive forested land square miles	non-productive forested land square miles	area square miles	per cent of total land area square miles	agricultural land square miles	waste and other land square miles	land square miles	water square miles	total square miles
Prince Edward Island .	725		725	33·2	1,356	103	2,184		2,184
Nova Scotia . . .	11,950	50	12,000	57·8	5,733	3,010	20,743	325	21,068
New Brunswick . .	21,773	189	21,962	79·9	3,445	2,066	27,473	512	27,985
Quebec . . .	303,500	70,000	373,500	71·3	18,922	131,112	523,534	71,000	594,534
Ontario . . .	170,000	70,000	240,000	66·1	35,523	87,579	363,282	49,300	412,582
Total Eastern Provinces .	507,948	140,239	648,187	69·2	64,979	224,050	937,216	121,137	1,058,353
Manitoba . . .	30,500	62,500	93,000	42·3	31,439	95,284	219,723	26,789	246,512
Saskatchewan . .	42,160	40,000	82,160	34·5	96,635	59,180	237,975	13,725	251,700
Alberta . . .	93,075	37,560	130,635	52·5	85,557	32,608	248,800	6,485	255,285
Total Prairie Provinces .	165,735	140,060	305,795	43·3	213,631	187,072	706,498	46,999	753,497
British Columbia . .	85,780	123,760	209,540	58·0	9,400	140,339	359,279	6,976	366,255
Total all Provinces . .	759,463	404,059	1,163,522	58·1	288,010	551,461	2,002,993	175,112	2,178,105
North-West Territories and Yukon . . .	10,000	50,000	60	4·1	10,067	1,393,496	1,463,563	53,195	1,516,758
Grand totals . . .	769,463	454,059	1,223,522	35·3	298,077	1,944,957	3,466,556	228,307	3,694,863

Note.—Figures from ' Economic Aspects of the Forests and Forest Industries of Canada,' by J. D. B. Harrison.

AFFORESTATION POLICY IN THE UNION OF SOUTH AFRICA

(Prepared in the office of the Director of Forestry)

THERE are few countries in the world more poorly endowed with natural timber resources than is the Union of South Africa; only 0·5 per cent of its total area is covered by indigenous high-forest. These forests are, moreover, composed mainly of hardwood species which are of limited economic importance and approximately 80 per cent of the forest area is already over-exploited. While indigenous timber played a most significant part in the early settlement and subsequent development of the country, there are few who still believe that local indigenous forests should or could be further exploited so as to make a substantial contribution to the future economic and industrial life of the nation. Research upon the silviculture of indigenous forests, particularly during the past twenty-five years, has shown that the present annual wood increment per acre is very low; the possibility of increasing this increment by systematic management so as to bring these forests within the range of economic forestry is, moreover, extremely remote. The significant contributions which the indigenous forests might make to the national interest in future are to be sought in directions such as water conservation and popular recreation rather than in commerce.

More than fifty years ago it was realized that indigenous species offered no scope for commercial afforestation in the Union and that suitable exotic species would have to be found and used for this purpose. Thereafter followed a long period of intensive introduction and trial of hundreds of hardwood and coniferous species selected from all parts of the world with climatic and soil conditions comparable with those prevailing in the Union. Conspicuous success attended this policy. It is estimated that to-day there are approximately 1,500,000 acres of plantations of exotics in the Union, of which approximately 350,000 acres comprise coniferous species and almost 1,000,000 acres eucalypts and tan-bark wattles.

Of the area under eucalypts and wattles, only 10 per cent is state owned as these species are usually raised as short rotation crops which are admirably suited for private investment. Apart from the production of wattle bark and extract, almost all of which is exported, the great bulk of the wood produced by the eucalypt and wattle industries is consumed by the gold mines on the Rand. No further extension of plantations for the production of mining timber is warranted. Existing hardwood plantations are capable of producing approximately 60 million cubic feet of timber per annum, which is adequate to cope with probable future demands, even if the rate of mining is considerably accelerated.

It is estimated that of the world's total trade in wood, approximately 80 per cent is composed of coniferous timber used principally for construction and building purposes, packing materials and pulp. Almost the

whole of the world's softwood timber supplies are concentrated in the northern hemisphere. The hardwoods from temperate regions, used for staves, sleepers, furniture, cabinet work and other special purposes constitute about 18 per cent, while tropical hardwoods, used mainly for furniture and veneer woods, are only 2 per cent of the total. The view that the still abundant supplies of tropical hardwoods will ultimately replace the softwoods of commerce to an appreciable extent does not warrant serious consideration in view of the basic unsuitability of these hardwoods for the purposes under consideration.

It is therefore the production of long rotation coniferous timber that constitutes the main task of forestry in South Africa if a considerable measure of independence of overseas supplies is ever to be achieved. As financial returns from afforestation with conifers are relatively deferred, the main responsibility for afforestation in this category devolves upon the state.

Of the 350,000 acres of conifers referred to above, approximately 80 per cent are state owned. Since 1920 state afforestation with conifers has proceeded at the rate of 12,000 to 14,000 acres per annum and only during the war years was this rate drastically cut. This policy has had a pronounced impact upon industry. During the past year the Department of Forestry produced almost exclusively from the thinning of immature plantations, 16,000,000 cubic feet of sawlogs. If to this is added the 5,000,000 cubic feet of sawlogs made available from the clear felling and thinning of privately owned plantations during the same period, it will be seen that a total volume of 21,000,000 cubic feet of softwood sawlogs was contributed from local sources to the maintenance of industry during a period of critical shortage of timber in this category. Working upon a 40 per cent factor of conversion from logs of immature size to deals, scantlings and shook lumber, this total represents approximately 8,400,000 cubic feet of sawn timber.

This volume of sawn timber comprises approximately 30 per cent of the average volume of softwoods imported into the Union during the five immediate pre-war years and probably more than 60 per cent of the current reduced consumption of sawn softwoods. In view of the fact that the local sawmilling industry is barely eleven years old, this achievement is remarkable. It should, however, not be taken out of its context. Scores of sawmills were established during the war years owing to the marked rise in the value of standing softwood timber (which made additional supplies available) and in the price of softwood boxes and building material. The gradual depletion of such sources of supply inevitably means that many of these mills will sooner or later go out of operation and that, for a temporary period at least, it will not be possible to maintain the present rate of production.

Despite the very limited amount of first quality forest land available in South Africa, the productivity of such land relative to world standards is phenomenally high. This is due to an unusually favourable combination of factors comprising rainfall, temperature, humidity and soil, as well as to silvicultural technique developed for conditions prevailing in the Union. The mean annual softwood increment per acre in South Africa varies from 40 to 390 cubic feet, depending upon site quality and species. A suitable

selection of fast and medium fast growing pines on land which is a mean between first and second quality may be estimated to yield a mean annual wood increment of 280 cubic feet per acre per annum. Compare this with the mean increments for the following countries : Germany, where the practice of forestry was most advanced, 50 cubic feet ; Sweden, 37 cubic feet ; Russia, 35 cubic feet ; U.S.A., 13 cubic feet ; Canada, 7 cubic feet. While these data apply to the entire commercial forest areas of the countries concerned and would have to be raised appreciably for selected sites under intensive management, they nevertheless indicate the wide margin of increment, due mainly to climate, which favours the South African producer of softwood timber. In other words, it takes at least two to ten times as long to produce sawlogs of a given mature size in the colder countries of the northern hemisphere as it takes to produce logs of similar dimensions in selected South African localities.

The animal and crop production capacity of South African land is low. The production capacity of afforestation as envisaged here is a notable exception to this general rule. In European countries the policy of restricting afforestation to poor and cheap non-agricultural land is widely applied ; the best land is reserved for pasturage and agricultural crops. This concept has strongly influenced South African policy and demands revision in the light of South African experience. In the high rainfall mountain areas, which are particularly well suited for afforestation in the Union, the topography and leached acid soils preclude the establishment of intensively managed grazing or agricultural crops. The value of land in such areas has risen only because of the profits made from the production of timber. In such watersheds long rotation forestry is the optimum form of land use, not only from the view of production and profitability, but also from the view of soil amelioration and conservation, erosion control, and regulation of stream flow.

If the effects of trade booms and depressions are ignored, it may be concluded that during the past century or longer there has been a gradual but significant rise in the world price of timber. With the depletion of supplies which will result from the mining of the virgin forests of the world now in progress, and with the increased demand for timber which will result from the industrialization of backward peoples, it is safe to surmise that the price of lumber (excluding periods of abnormality like the present) will continue to rise. Even if the view that vast supplies of virgin timber (as in Russia) are still available, is conceded, the trend in price will nevertheless be upward owing to rising wage levels, increased inaccessibility and relatively higher costs of transport. All countries will have to rely increasingly upon home-grown (as opposed to virgin) timber supplies, and it is improbable that the great timber exporting countries, which have a high *per capita* consumption of wood, will ever have an appreciable surplus of home-grown wood available for export. Under any system of fair and controlled world trade, the future position of the South African softwood producer will tend to become more favourable *vis-à-vis* his competitor, the overseas exporter of timber.

Exhaustive tests upon the quality of softwood timber grown in South Africa, carried out particularly during the past ten years at the Forest Products Institute in Pretoria, have shown that this timber, class for class,

compares favourably with imported timber. While irresponsible elements in the sawmilling industry, particularly during the war years, did great injury to the prestige of South African timber by marketing badly sawn and unseasoned timber, it is believed that the system of compulsory grading now under consideration for all softwood produced in the Union, will rapidly restore the position.

If all the suitable land now held by the Department of Forestry is afforested with conifers, it is estimated that half a century hence its sustained yield will approximate 70,000,000 cubic feet of sawlogs. With the probable contribution of private enterprise it is unlikely that this figure would exceed 90,000,000 cubic feet at that date. The foregoing résumé gives in brief outline the reasons why the Union Government has now incorporated into its plan for post-war reconstruction the policy of acquiring hundreds of thousands of acres of land suitable for afforestation and the encouragement of private afforestation so that, half a century hence, the production capacity of the Union may approach the figure of 200,000,000 cubic feet of softwood sawlogs which is the estimated timber consumption capacity of the country at that date.

PROBLEMS OF LAND UTILIZATION AND CONSERVATION IN NEW ZEALAND

By L. I. Grange, D.Sc., W. M. Hamilton, D.Sc., and P. W. Smallfield, M.Agr.Sc.

Of the total area of 66 million acres in New Zealand nearly 43 million ares are occupied. The remaining 23 million acres comprise rivers, lakes, roads, forest and scenic reserves and mountainous areas unfit for settlement.

Of the occupied area 17,489,548 acres (40·7 per cent) are in sown grassland and a further 13,869,330 acres (32·3 per cent) are in tussock or other native grassland. Sown and native grassland together, therefore, cover 73 per cent of the total occupied area. Approximately 1¼ million acres (2·9 per cent) are sown in field crops and a further 230,000 acres are fallow or used for orchards, market gardens, etc. Of the remaining area 860,000 acres (2 per cent) is in plantations, 2,886,000 acres (6·7 per cent) in forest and 6,393,000 acres (14·9 per cent) is in scrub or other unimproved areas.

The 17½ million acres of sown pasture land consists of approximately 11 million acres of surface-sown hill grassland established after forest or scrub fires and 6½ million acres of pasture sown on ploughed land. The 1¼ million acres in crop include nearly a million acres in supplementary fodder or root crops, so that, adding this area to that in grassland, stock is grazed on approximately 32½ million acres. This may be sub-divided according to the type of farming practised—estimated areas are shown in tabular form below.

	estimated areas in millions of acres		total
type of farming	North Island	South Island	
dairying . . .	3·3	0·5	3·8
fat lambs and other fattening farms . . .	2·5	2·3	4·8
hill sheep farms . .	8·0	14·5	22·5
lowland sheep farmers—little or no fattening .	—	1·4	1·4
Totals . .	13·8	18·7	32·5

The problems in land utilization can be considered according to the topography of the country since utilization is mainly dependent on this factor.

The average of soils in the North and South Islands on topographic basis is :—

topography	North Island (acres)	South Island (acres)
flat and rolling . .	8,144,000	4,789,000
hilly land . . .	48,281,000	31,752,000 (hilly land and steep)
steep	14,740,000	

FLAT AND ROLLING LAND

With the exception of the types mentioned below the use of flat and rolling land presents no problems beyond the application of fertilizers and drainage. The soils generally require dressings of lime and phosphate for pastures and most crops Exceptions for lime and phosphate are the first bottom lands, and for lime the pumice soils and immature soils derived from mudstone. Sandy soils in high rainfall areas need as well potash. The lime requirement of all our soil types is known from soil studies and from actual responses on small trial plots. This provides a sound basis for tests of soils from farmers' fields in order to advise on the amount needed on a particular field. A fourfold or more increase in liming of the flat and rolling land to bring the soils to a lime content that plants demand for best growth is necessary. Tile and mole drainage of heavy loams on some farms is practised, but more farms could be drained in this manner to increase carrying capacity.

The agricultural utilization of the following ploughable soils has presented difficulties.

(*a*) *Mature brown loams and related soils derived from basic volcanic rocks, locally called ironstone.* These on cultivation work up to a good tilth, but so far pastures even with heavy dressings of lime and phosphate rapidly deteriorate. It is likely that phosphate fixation is here the limiting factor. Their total area is 100,000 acres.

(*b*) *Deep peaty soils.* These are very acid and contain practically no plant foods. Besides the heavy dressings of all fertilizers that are required to establish pastures, the peats present moisture and fire problems. With ordinary drainage they become too dry in the summer and too wet in the winter, control of water level in the draining by flood gates may effect some improvement. Fires form depressions that become water-logged. Their total area is 100,000 acres.

(*c*) *Sand podzols.* The pan in these soils maintains the water table at or near the surface in winter and in the summer the soils dry out

badly. All plant foods are in extremely low supply. The area of sand podzols is 130,000 acres.

(*d*) *Ground water podzols.* The ground water podzols, locally called pakihi soils, occur in districts with rainfalls ranging between 80 inches and 150 inches. In winter the ground poaches badly, and the absence of suitable run-off country for stock in the winter has prevented their development. As well, the high rainfall causes rapid leaching of fertilizers applied, with the result that heavy applications of lime and superphosphate would be needed each year. Their area is 250,000 acres.

(*e*) *High altitude land.* Easy topography land lying above about 2,000 feet has too short a growing period for pastures to be suitable for agriculture. Most of this land in the moderate to high rainfall areas has been taken for commercial forestry.

Altogether the easy land not adapted to agriculture is relatively small in total area—less than 1,000,000 acres.

HILLY LAND

Hilly land is the class that is moderately steep with slopes between 12 and 30 degrees. In the case of scrub land generally it can be brought into pasture if broadcasting of fertilizers—lime and phosphate—is practised. Sowings after forest burns come into good pasture, but deteriorate if not top-dressed. On many soil types care needs to be taken that soil is not eroded, and this can be achieved mainly by obtaining a close pasture cover. Where slips occur as on hard mudstone and sandstone country, widely spaced trees may be necessary to hold the soil.

Hilly lands not used for agriculture or employed only for poor class grazing are :—

(*a*) *Semi-mature podzols.* The vegetation is low scrub with rush in badly drained patches. A suitable seed bed for pasture cannot be obtained after burning the scrub and this, together with the difficulty of dealing with the badly drained patches, excludes them from agricultural use.

(*b*) *Pumice soils.* On hilly land pumice soils are difficult to bring into pasture for they erode by wind and water before a close sward is obtained. Some are already partly eroded by the opening of the scrub vegetation by fires.

(*c*) *Very low fertility soils.* In the southern part of the South Island there are several hundred thousand acres of hilly soils that are reverting to scrub and in some cases holdings have been abandoned. Dressings of phosphate and particularly lime beyond payable amounts are required.

Types (*b*) and (*c*) are better adapted to protective forests.

STEEP LAND

The utilization of steep land—slopes of 30 degrees and more—is New Zealand's greatest land problem. This class of land occupies about 60 per cent of the total area.

Soil erosion is the limiting factor, wind and water erosion removing topsoil, and slips removing topsoil and subsoil. There is only one kind of soil that presents little or no problem in its use—the soils of high fertility—which are mainly derived from slightly calcareous mudstone. Although some slips occur they rapidly grass over completely. More than half the steep soils are grazed by sheep and cattle, but, nevertheless, many of the runholders are faced with the difficulties caused by loss of fertility due to soil erosion. Soil loss occurs on the following classes of country :—

(*a*) *Low rainfall high country of South Island*

Sheet erosion by wind and water.

A soil erosion survey of the high country reveals that on a total area of 10,000,000 acres more than 75 per cent of topsoil has been lost on 623,000 acres, 50–75 per cent on 1,500,000 acres and 25–50 per cent on 3,000,000 acres.

Two causes have operated to deplete the native tussock vegetation—grazing by sheep and by rabbits, and burning. Soil loss followed the opening up of the cover and is greatest in the districts of lowest rainfall (17 in.). Factual data are required on the effect of burning—whether burning should be prohibited altogether or allowed at a certain time of the year, on spelling, and on the introduction of palatable plants. A search is being made for a station on which these experiments could be made and later to demonstrate methods of increasing the vegetation cover to arrest erosion.

(*b*) *Moderate to high rainfall country chiefly in the North Island*

(i) *Sheet erosion* occurs on soil derived from rocks low in plant food and minerals. The soils before grazing commenced were generally thin—about 4 inches—and now many patches occur where the soil is absent. Most of this land should be planted in protective forests.

(ii) *Slipping* is common in the North Island—it is prevalent on a greater area than is the sheet erosion. Its influence on grazing depends on the nature of the subsoil or rock exposed. Some expose a brown yellow loam that grasses over slowly, others expose soft sandy material of low fertility on which recovery is very slow and the resultant pasture not as good as the original, others have hard rock on which a soil develops extremely slowly, the first vegetation being moss. Another kind on soft mudstone slips repeatedly developing large gulches.

Grazing can be carried out under all types of slipping except on much of the land that exposes hard rock faces and on that which forms large gulches. Where the land is suitable for grazing despite the slips some means of lessening slipping should be tried and the most promising is the planting of widely spaced trees. The remedy on the bad slipping country is protective forest.

New Zealand readily settled into a pattern of land utilization that suits its climate, topography and soils, and it is difficult to see how it can be changed in its broad outline.

The limits of use of steep land types for grazing are now being investigated. It is probable that some of the grazing land will be planted in protective forest, mainly because of soil erosion. But the production lost by this action can be more than overtaken by the use of fertilizers on the remainder. A big improvement in carrying capacity of the hilly country will also take place with the use of fertilizers. In the process of adjustment care must be taken that afforestation is not overdone—steep land and hilly land that cannot be top-dressed economically may in the interests of the state need to be subsidized. Some attention is now being given to the possibility of sowing pasture seed from the air, but on much land this will be useless without distributing fertilizers as well, and this is a less promising proposition. On the land that is held in pasture there are erosion problems, but these cannot be classed as alarming and can be largely solved by common-sense methods.

AN OUTLINE OF THE PROBLEMS OF LAND UTILIZATION AND CONSERVATION IN INDIA

By Khan Bahadur Mian Mohammed Afzal Husain and Professor J. N. Mukherjee, C.B.E., D.Sc.

The population of the world is fast increasing as also the demand for food, houses, clothes and better amenities of life. Land use planning has thus assumed the same importance as industrial planning. It is gradually coming to be recognized as a major function of a State. A land use plan aims to secure the soil and water resources of a country against loss or damage. It undertakes to work out and maintain optimum levels of their utilization.

Some basic facts

India covers an area of 1·6 million square miles, i.e., about 1,000 million acres in round figures, which constitutes only 3·4 per cent of the land surface of the globe; but it contains about one-fifth of the entire human race. More than two-thirds of our population live on the land following methods of subsistence farming which again are determined by the exigencies of circumstances. An increasing population, a definitely insufficient level of nutrition of both man and livestock, and the poverty caused by the low acreage of arable land available per capita and by the undeveloped state of natural resources and industries require that utmost care should be taken of our land resources.

A land use plan has to reconcile many demands on land and water resources. For proper land use planning an inventory of these resources has to be made and the existing forms of land use surveyed. Apart from physical features, local, regional and national needs, as also social and economic aspects, will determine the land use pattern of a country.

From the point of agriculture and forestry these 1,000 million acres of land surface of India may be classified as follows: (1*a*, 1*b*).

Table 1

classification	acres in millions
area sown	362
cultivable waste other than fallow	171
current fallow	79
forests	107
net available for cultivation	281
total	1,000

'The area shown as not available for cultivation consists of land which is either barren or unculturable or covered by water, buildings and roads or is used for purposes other than agriculture' (*1a*, p. ii). The land available per capita for food production in 1940–1941 was about 0·67 acre. On the other hand, the yield per acre of the principal crops is very low in comparison with other countries.

TABLE 2

YIELD PER ACRE OF PRINCIPAL CROPS IN INDIA AND SOME OTHER COUNTRIES. (AVERAGE OF A NUMBER OF YEARS).

country	rice (2) lb	wheat (3) lb	cotton (3) lb	sugarcane (3) lb
India	700–900	650	90	28,700
U.S.A.	1,450	850	190	41,481
Egypt	2,000	1,800	450	58,240
Italy	3,000	1,150	—	—
China	1,400	939	—	—
Japan	2,300	1,350	200	—
Java	1,350	—	—	98,400–114,800

Improvement and maintenance of soil fertility, utilization, consistent with conservation, of all available land for food production, and the supply of raw materials for industries constitute some of the major objectives in land use planning in India. The information regarding the areas shown as culturable waste other than fallow, current fallow, and the area not available for cultivation, is rather meagre. Reliable and detailed information remains to be collected for these areas. During the past few years some land has been diverted to food production and plans for reclamation of waste lands have been undertaken. These attempts, however, have so far touched only the fringe of the problem.

CONSERVATION OF LAND RESOURCES

It is obvious that the conservation of land resources assumes special importance in India. The menace of soil erosion is a serious problem. Devastating floods are not uncommon. Dust storms occur over thousands of square miles as a regular feature in summer. Most of the rivers carry downstream huge quantities of silt and their turbid waters tell the tale of widespread erosion. The problems of erosion will be discussed later.

Owing to the peculiar climatic features, water constitutes the most important limiting factor in agricultural production. The conservation and planned utilization of water resources are thus vital to the economy of the country. The great rivers of India should be capable of providing water for irrigation of millions of acres, of supplying hydro-electric power and providing water transport on a vastly greater scale than at present. Development of fisheries has also enormous possibilities. Greater attention is being paid to these aspects in recent years. The area already under irrigation from all sources is estimated to be 60 million acres—a great achievement in itself—and several hydro-electric schemes are in operation, but much remains to be done.

Recently several projects have been undertaken, of which the Damodar Valley project deserves mention, as it is a multiple-purpose scheme. A Central Waterways, Irrigation, and Navigation Commission has been set up to deal with problems of flood control, soil erosion, drainage and land reclamation, irrigation and navigation. It will conduct surveys and investigations with a view to securing planned utilization of surface and subsoil water resources, and press forward schemes for the consideration, control and regulation of water and waterways in consultation with other government agencies. Large scale projects estimated to cost over 1,000 million rupees are contemplated. A comprehensive hydrological survey of surface and underground waters has to be undertaken.

In all land use planning and conservation measures the active and willing participation of rural communities is a necessity. In spite of widespread illiteracy the Indian peasant is no fool. He shares the conservatism of the farmer in other countries. His enthusiasm can be evoked only if his problems are treated as he sees them and he derives tangible benefit from such treatment. An efficient organization is needed for effecting contact with him for helping the solution of his problems based on a thorough study of the merits and demerits of his practices and of his difficulties.

Erosion

All forms of erosion are met with. Over the greater part of the country the rainfall is concentrated between June and September. Precipitation is often very heavy. Encroachment on natural forests has already produced widespread erosion. In the hilly regions land slides are not uncommon on steep slopes. A journey across the country by railroad or by air reveals the widespread havoc gully erosion has caused over vast tracts. It has been estimated that in the United Provinces, North-West Frontier Provinces, and the Punjab alone, the gullied land, amounting to about 5,000 square miles, has been rendered completely useless.

Apart from over-grazing, which is one of the most important causal factors of erosion, people living in hilly regions take recourse to shifting cultivations known as *jhum* in Assam and *kumri* in Madras. The practice, however, is localized in certain limited areas and is disappearing. In the Punjab shifting cultivation 'was put a stop to long ago.' (4).

Wind erosion occurs on a large scale especially in the semi-arid and arid tracts. In the deltaic regions river erosion sometimes lead to the wholesale destruction of villages and the formation of new lands known as *Char*. In Eastern Bengal, once prosperous settlements have disappeared. The shifting courses of rivers in deltaic areas have given rise to what is known as *bihl* areas, which are inland lakes or large swamps. Many of these should be used for fisheries or wild life preservation or put to better purpose by reclamation. Erosion by waves is not unknown along the coast lines.

Sheet erosion is quite common in the plains in regions of heavy precipitation. Bare lands, either on slopes or on level ground, suffer from it as also sloping cultivated land with standing crops. Measurements of the run off in scrub jungles in the Kangra district and in black cotton soils at Sholapur have shown that considerable losses of soil take place from sheet erosion. A loss of 133 tons of soil per acre per annum from a well tilled

field has been recorded. Not being spectacular, the seriousness of sheet erosion is not so widely recognized.

In the following a brief account is given of erosion surveys and of the steps taken to control erosion in some of the Provinces (6). In the Punjab, besides collecting the basic information, wide measures of control have been undertaken in particular areas. Serious erosion is confined to the belt of the foothills and sloping ground formed by the main Himalayan lower slopes, the Siwaliks and other outlying rocky hills of Gurgaon in the east and the Salt-Range in the west. It covers an area of about 35,000 square miles. The evil effects of erosion spread outside this belt. For instance, the enormous load of silt largely delivered from Jammu and Gujrat hills and carried by the Jhelum river has decreased the carrying capacity of the upper Jhelum canal by 40 per cent even with the installation of several silt ejectors. In the Uhl catchment area the erosion is spread over 150 square miles of very steep hills having 6,000 feet to 16,000 feet elevation. According to the intensity of erosion four belts have been distinguished. As control measures cultivation on unterraced slopes and the heavy grazing of flocks have been completely stopped. In the Jhelum canal area, by afforestation and bunding, the torrent intensity has been reduced from 1,000 to 100 cusecs. A survey of the district shows that about 50,000 acres of cultivated land have been destroyed by the Salt Range torrents before they join the Jhelum river. Heavy grazing on hill slopes being one of the main causes of erosion, closures are enforced by law. The effects of such measures have been so marked that even voluntary closures have been undertaken by local inhabitants. The following figures give an idea of the total area closed to grazing up to 1 April 1945 :

by Chos (Torrents) Act .	495,168 acres
by Forest Act . .	106,851 acres
by private enterprise .	16,808 acres

In the Bijapur and Sholapur districts of Bombay, contour bunding and trenching, gully-plugging, afforestation and other methods have been used as control measures to check erosion in about 133,000 acres of cultivated land. It has been possible to increase the yields of crops three to six times by taking recourse to erosion control measures. (6).

Ravines occur extensively in the Jumna river basin of the United Provinces. Attempts to afforest with Kikar (*Acacia arabica*) having failed, the tract was closed to grazing. Incidental attempts at afforestation at this stage resulted in dense growth of grass, and gradually the old indigenous forest trees reappeared. (6).

The Jammu Erosion Committee in Kashmir reported that the areas affected comprised 820,815 acres of cultivated and 1,273,447 acres of uncultivated land in 1927, which have respectively increased to 860,495 acres and 1,314,836 acres in 1937. Removal of vegetation, over-grazing, inefficient farming, accidental and intentional fires have been recorded to be the main causes of erosion. (6).

The Indian peasant knows through years of practical experience the simple methods of checking erosion by means of terracing, bunding, growing trees or grasses. Terracing has been the usual practice on slopes where inferior millets, paddy and other crops are cultivated. In Assam,

the 'Jhum' lands are kept fallow for at least four years to allow grass or shrubs to grow before it is again 'jhummed,' which diminishes the evil effects of this practice.

The following remark, which refers to the Punjab where more has been done to control erosion than in other parts of the country, will show how much remains to be done : 'Indeed we have as yet done little more than blaze a trail and that only in some of the districts in which the problem must be faced.' (7).

Forests

The hundred and odd million acres of forest in India are unevenly distributed as will be seen from the following table . (5).

Table 3

Forest area (in square miles)

province	total area		forest area	percentage of total forest area
Ajmer-Merwara . . .	2,367		73	3
Assam	55,445		22,841	41
Baluchistan . . .	52,925		2,218	4
Bengal	78,708	(1)	7,216	9
		(2)	6,673	8
Bihar	69,348	(1)	4,242	6
		(2)	5,675	8
Bombay	76,026	(1)	7,615	10
		(2)	5,305	7
Central Province and Berar .	98,573	(1)	33,497	34
		(2)	13,889	14
Coorg	1,582	(1)	760	48
		(2)	422	27
Madras	125,163	(1)	16,985	14
		(2)	16,694	13
N.W.F.P.	13,099	(1)	199	2
		(2)	394	3
Orissa	32,398	(1)	1,526	5
		(2)	2,412	7
Punjab	96,830	(1)	1,771	2
		(2)	4,732	5
Sind	47,155	(1)	1,135	2
United Provinces . .	106,248	(1)	5,412	5
		(2)	11,960	11
		(1)	105,468	12
total .	858,375	(2)	70,374	8

Note : (1) merchantable (2) inaccessible or unprofitable.

About 12 per cent of the total area is covered by merchantable forest, but the percentage varies from 2 to 48 in different parts of the country. Besides, the forest areas occur in most cases concentrated in blocks. The first consideration in forest policy should be the 'preservation of the climatic and physical conditions of the country' (5, p. 17), with a view to prevent floods, erosion or desiccation. The forests situated in hilly countries which contain headwaters of the rivers thus require to be protected. The Forest Departments have recognized this for a long time. In eroded and many arid and semi-arid tracts an energetic policy of afforestation has to be undertaken. Apart from this, a judicious policy for securing a widespread distribution of forests over the whole country, especially of village forests, is a necessity. The climatic peculiarities also render such a distribution desirable for conservation of atmospheric precipitation. The rural population depend on village trees for their supply of fuel and timber for the construction of houses and agricultural implements, etc. The fruit supply is inadequate and many more village orchards and fruit trees in homesteads are needed. The importance of trees has been long recognized by the people and the planting of trees has been encouraged. There is great scope for tree cultivation in much of the area shown as cultivable waste other than fallow and current fallow, as also in the area shown as not available for cultivation. Trees along roads have been an old feature, but a more systematic plan is necessary to replenish those lost by age, storms and by human interference.

It has been estimated (5, p. 20) that the minimum percentage of properly managed forests to the total area should be between 20 and 25. It is, however, recognized that the demand for land for food production should be given preference over forests wherever this is consistent with conservation. While forests under government management are well looked after, private forests are not. The accessibility to the forest areas leaves also a good deal to be desired in many regions.

During the last two wars forest resources have been drawn upon on an unprecedented scale. While the Forest Department has since its inception managed all forests under its control on the principle of sustained yield, which ensures that the forest produce does not decrease from year to year, that the yearly yield is equal or gradually rises till the maximum yield is obtained (5, p. 2) the effect of this unusual demand deserves immediate and close attention.

The climatic conditions vary widely in different parts of the country. In Malabar and some parts of North-East India, the annual rainfall is in excess of annual evaporation. This excess is most pronounced in the coastal regions and in Assam. Elsewhere evaporation is predominant over rainfall. Conditions indicative of the other extreme occur in the Thur desert and parts of the desert valley of Sind, being most marked in the vicinity of Sukkur in the Sind Province. Several types of forests are recognized to occur (8). Excluding the mountainous regions, the four major rainfall vegetation regions are : (9)

(*a*) Evergreen forests in the wet zone with rainfall over 80 inches ;
(*b*) deciduous or monsoon forests in the intermediate zone with a rainfall of 40 to 80 inches ,

(*c*) dry forest and scrub-land in the dry zone with a rainfall of 20 to 40 inches ; and
(*d*) desert and semi-desert types of vegetation in the arid zone of less than 20 inches.

In the wet and intermediate zones regeneration of forests is quick. In the north-western part of India where the rainfall is not less than 20 inches, forests of the tropical dry thorn type will grow. In dry regions with rainfall below 20 inches ' the forest is more scrubby and consists of even drier and scanty thorn forest ' (5, p. 31). At other regions the rainfall is below 10 inches and where the rainfall is very low, complete desert conditions prevail. ' But even here, over much of the area forests of a sort, sufficient to provide fuel and some small timber could still be grown, and so long as the plants could be watered for the first two or three years.' ' Where proper irrigation is available good forests could be grown over much of this area, provided suitable species were chosen ' (5, p. 69). It has been suggested that the afforestation of the area below the 30 inches rainfall line is desirable, if not for anything else but to set up a ' barrier against the spread of desert conditions and preserve the fertility of the Gangetic plain to the east of the 30 inches rainfall line ' (5, p. 70).

Apart from timber and fuel, a wide range of minor forest produce is obtained from the forests, of which mention may be made of myrabolam, essential oils, dyeing and tanning substances, gums and resins, fibres and greases, bamboos, lac, medicinal herbs, and wax. The annual value of timber, fuel and woodware in recent years will be about 150 million rupees and that of minor produce 40 millions. Forests provide permanent employment for about 1½ million workers and their dependents. The development of industries based on forest produce constitutes one way of reducing the pressure of population on arable land (10).

Coal production

In an article under subject (*a*), the problems of agriculture in India have been discussed with reference to food production and it is not necessary to cover the same ground at length. India faces a permanent shortage of food-stuffs and her requirements of cereals alone may amount to about 21 million tons in 1955, if a major part of the population continues to depend almost exclusively on cereals for all nutritive elements. In any attempt to find a solution of this and other problem of agriculture, the productivity of the land assumes a fundamental importance. This subject has also been discussed at length in the article referred to. The present low yield per acre does not seem to be inherent either in the soil or in the climate.

Figures given in table 4 show the acreage and yield of principal crops of India (11).

The acreage under plantation crops which are not normally shown in the forest area is 3·25 million and the value is estimated at 350 million rupees. In 1943–1944 India produced 560 million pounds of tea, 35 million pounds of coffee and 35 million pounds of rubber (11).

Water being the most important factor limiting crop production, extension of facilities for irrigation must have high priority. There are

many potential sources yet untapped for this purpose. The progress of irrigation is indicated by the following figures :

	1924–25	1936–37	1940–41
total area	52,766	60,510	66,958
area irrigated from government canals	21,841	26,940	29,697

TABLE 4

AREA AND YIELD OF PRINCIPAL CROPS OF INDIA.

crops	1924–25	1936–37	1940–41	1943–44
(*a*) rice :				
area (in acres) . .	69,329	72.295	73,059	79,960
yield (in tons) . .	26,005	27,824	32,150	30,603
(*b*) wheat :				
area (in acres) . .	31,779	33,215	34,849	33,740
yield (in tons) . .	8,867	9,762	10,027	9,690
(*c*) other cereals : (jowar, bajra, maize) :				
area (in acres) . .	56,687	59,714	57,380	63,813
yield (in tons) . .	10,682	11,477	12,363	12,803
(*d*) oil-seeds :				
area (in acres) . .	18,258	21,782	23,725	24,802
yield (in tons) . .	3,604	4,665	5,777	5,760
(*e*) cotton :				
area (in acres) . .	26,449	24,759	23,311	20,420
*yield (in bales) . .	6,018	6,234	6,080	5,072
(*f*) jute :				
area (in acres) . .	3,115	2,889	2,160	2,060
*yield (in bales) . .	8,940	8,656	5,460	5,479
(*g*) sugarcane :				
area (in acres) . .	2,532	4,440	4,598	4,234
†yield (in tons) . .	2,546	6,476	5,794	5,848

* 1 bale = 400 lb   † relates to raw sugar (gur)

Considerable areas are more or less affected by salts, e.g., 2 million acres in the United Provinces. As a result of irrigation in the Punjab, saline and alkaline conditions and water-logging have rendered large areas unsuitable for cultivation. Estimates of such damaged land vary from one half to 2 million acres. About 25,000 acres or more are said to be going out of cultivation each year. Reclamation projects have been undertaken to deal with this menace (6).

The second important factor in increasing productivity is the use of manures and fertilizers, very little of which is consumed at present, especially for cereals, oilseeds and pulses. More intensive attention has also to be paid to the development of existing, or to the working out of new systems of crop rotation.

The Agricultural Departments have to their credit considerable

achievements in the field of improved varieties, although the effects of the introduction of these have not yet been felt in the yield per acre to a large extent, excepting sugarcane. One possible reason is that the percentage area under improved varieties is yet small. The areas under improved varieties of principal crops in 1936–1937 were as follows : (11)

AREA (IN THOUSAND ACRES) UNDER IMPROVED VARIETIES

rice	wheat	cotton	jute	sugarcane	all crops
3,320	8,330	4,864	1,314	3,197	22,430

PASTURE

In 1936–1937 the bovine population of India was about 150 millions, which constitutes about a quarter of the total world figure, but the land area is only 3·4 per cent of the total. In addition, sheep and goats number about 100 millions (in round figures), making a total of approximately 250 millions, while the area under fodder crops was 15 million acres (11). The old villages pastures have been considerably encroached upon with the increase in population. The pastures are over-grazed and their nutritive value is, generally speaking, very low indeed. The forests provide grazing grounds for a considerable number, but they have suffered widely because of over-grazing caused by lack of control. More attention is, however, being paid to the evil effects of over-grazing and to its control.

SOIL SURVEYS

Land use planning for agricultural and other purposes necessitates soil surveys with a view to grouping the soils according to their suitability and ratings of productive capacity. For planned production of crops, extension of forests, control measures for checking erosion, reclamation of saline and alkaline lands, and for the determination of the best form of utilization of waste and fallow lands, systematic soil surveys are urgently necessary. The suitability of soils for different purposes and treatments have to be worked out in fair detail. Soil surveys are also necessary for these purposes. Much information is available which, however, requires to be collated and supplemented. Soil surveys on the profile basis have scarcely been begun. The position regarding soil surveys in India is to be dealt with in a paper in the evening discussion on this subject, and a reference may be made to it.

ROADS, RAILWAYS, AND WATER TRANSPORT

Roads and railways, although they do not cover a very large percentage of the land area, occupy a very important place in land use planning. In India transport is a matter of great difficulty, and a handicap in economic and social development. In 1944–1945 the total railway route mileage of all types was 40,509. It is, however, concentrated in certain areas. The total mileage of roads in British India in 1937 was about 300,000. Metalled roads form 77,000 (in most parts motorable) miles out of this total (11). In addition, several million miles of village mud roads exist. In regions of high rainfall they are often impassable during the rains and generally unfit for motor vehicles. The facilities for transport in all shapes and of

better types require to be increased enormously, and are a matter of urgent importance. One of the considerations in the lay-out of roads and railways, apart from tapping centres of production, existing or potential, is the desirability of avoiding encroachment of better arable lands and the interference with natural drainage which has produced in the past disastrous consequences. A co-ordinated picture of the demands of these various aspects has to be obtained in order that land use plans may meet them. There is considerable room for development of water transport. Navigation canals are only 3,800 miles in length. 'Irrigation canals and rivers are navigable for about 25,000 miles' (10).

Village and town planning

The present population of India is more than 400 millions and its annual rate of growth is about five millions. The population is distributed over 655,892 villages and 2,703 cities and townships having a population of over 339 millions and 49 millions respectively. The urban : rural population ratio is 1 : 72 (12).

According to the *Census Report of India*, 1941 'a town is a place of not less than 5,000 inhabitants possessing definite urban characteristics.' However, outside the 2,703 cities and townships there are 1,521 places with a population of over 5,000 in which urban facilities do not exist. The classification of towns and villages by population of 5,000 and over is given below : (12)

population (*in thousands*) . .	5–10	10–20	20–50	50–100	100
number . .	3,017	733	321	95	58

During the last twenty-five years, the number of cities with a population of 100,000 or more has increased from 35 to 58 and the aggregate population of these cities has risen from 9 to 16½ millions (11). The following table (12) will illustrate the progress of urbanization in certain Indian cities during the two decades between 1921 and 1941 :

Table 5

Population increase (in thousands) of certain Indian cities

	1921	1931	1941
Calcutta . . .	1,046	1,163	2,108
Bombay . . .	1,175	1,161	1,489
Madras . . .	527	647	777
Lahore . . .	282	430	672
Delhi . . .	248	348	522
Cawnpore . .	216	244	487
Karachi . . .	202	248	359
Allahabad . .	157	184	261
Nagpur . . .	145	215	302
Patna . . .	111	145	176
Travancore . .	73	96	128
Coimbatore . .	66	95	130

The density of population per square mile varies from 9 in Baluchistan to 953 in Cochin. 'It is a well-known fact that the density of population in India is largely conditioned by rainfall and soil fertility; numerous instances can be pointed out of a rural area having a larger density than an urban area. The position has shown no fundamental change between the censuses of 1921 and 1941, but one should not overlook the fact that during this period the Indian States have shown a larger relative increase in density than British India. It should be stated here that the Indian States are not so densely populated as British India' (11, p. 2). The following table illustrates the progress of population in India: (11)

TABLE 6

POPULATION OF INDIA

	1921	1931	1941
total population	305,647,000	338,089,000	388,997,000
density per square mile	195	215	245
Distribution between towns and villages.			
urban	31,128,000	37,414,000	49,696,000
rural	274,519,000	300,675,000	339,302,000

It will be seen that India is in for urbanization on a big scale and that it will affect pronouncedly the really large town rather than the smaller ones. The towns are spreading willy-nilly without any plan; 'but where industrialization is developing and population growing rapidly, it is essential that an accommodation be reached between the individual town or house-builder or speculator, and the region as a whole in the sense of the best use and conservation of the land and in fact the fullest harmony between urban and rural' (12).

The reasons for this distillation of population from rural to urban areas are many. 'Industrialization which tends to produce large aggregations' (11, p. 2), the absence of adequate avenues of employment in the villages caused by the deterioration of rural industries based on mediaeval methods, the dearth of transport facilities and of medical aid, backwardness of hygienic conditions, want of facilities for education, and in general, the absence of amenities of life; are all causes which have contributed to this transfer of population. Very little attention has been paid to this development of rural areas, where agriculture is the only industry worth mentioning, and it has been left to the poorest and the least advanced section of the community.

The problems of town and villages planning on a large scale have to be faced. The population distributed over 600,000 odd villages will have to be concentrated in a suitable number of larger centres. This is necessary in order to provide adequate facilities such as transport, schools, medical aid, demonstration farms, storage accommodation for agricultural produce and fertilizers, markets, and all such other things, which would put village

economics on a sound footing and ensure development of the rural population and secure for them their due share in national progress. The number of villages with a population below 5,000 is 650,000 and there are only 4,224 townships and cities with a population above it. This large number of villages has to be reduced significantly. This can only be a long term project. But transport development in itself, if properly planned, will go a long way to facilitate it.

The planning of modern villages and townships is another important but complex problem. Town planning for the bigger cities has been carried out with more or less tangible results. It has been left mainly to municipal corporations and to special authorities set up by the Government. In view of the importance of town and village planning from the point of view of the well being of the people, it should be considered to be a definite function of the State.

With progressive industrialization sites have to be provided for factories and townships for housing the population associated with them. Over-concentration of population has to be avoided. Transport facilities and supply of raw materials, food-stuffs and other requirements of the population have to be provided. Encroachment on arable lands should be minimized so far as is possible. Subsidence in mining areas with consequent water-logging and damage to valuable arable soils has occurred in the coal basins of Bihar and Bengal. The impetus to industries given by the two world wars has brought into existence a large number of factories which are mostly concentrated in particular areas, which has created new problems. A balanced development between agriculture and industries requires a judicious distribution of rural and medium-sized industries all over the country. All these involve land use planning.

Preservation of wild life, national parks and sites of archæological and historical interest

Laws for the preservation of game, wild life, as also of historical monuments, are in existence. There is, however, no doubt that these aspects of land utilization have received cursory attention, excepting the preservation of historical monuments for which definite action was taken by the late Lord Curzon as Viceroy and Governor-General of India. There are many beautiful landscapes worth preservation. Many waste lands could better be left to nature for reclamation. There is great scope for the development of national parks, bird sanctuaries, and methods of preservation of rare flora and fauna in general. The experience of other countries will be of great help in this field.

Co-ordination and planning by the State

The problem of land utilization and conservation, the reconciliation of rival demands on land and water resources, the formulation of land use plans, and their translation into practical measures involve so many aspects, physical, social, economic, local, regional and national that they could best be tackled by an organization which will ensure efficient co-ordination between the various agencies dealing with these different aspects.

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REFERENCES

(1) [a] *Agricultural Statistics of India*, 1937–1938, **I.**

(1) [b] *Agricultural Statistics of India*, 1937–1938, **II.**

(2) I.C.A.R. *Memorandum on the development of Agriculture and Animal Husbandry in India*, New Delhi, 1944.

(3) *Indian Textile Journal*, 1945, **56,** 7.

(4) Glover, Sir Harold. 1944. *Erosion in the Punjab, its Causes and Cure.*

(5) Howard, Sir Herbert. 1944. *Post-war Forest Policy for India*, New Delhi.

(6) I.C.A.R. *Report of the All-India Soil Survey Scheme.* (Not yet published).

(7) Penny, Sir James. Foreword to reference 4 above.

(8) Champion, H. G. 1936. *Indian Forest Records.* (*New Series*)—*Silviculture,* **I,** No. 1.

(9) Stamp, Sir Dudley. 1939. *Asia : A Regional and Economic Geography.* Fourth Edition, London.

(10) Lorenzo, A. M. 1944. *Atlas of India.* Oxford University Pamphlet on Indian Affairs, No. 16.

(11) Subramanian, S., and Homfray, P. W. R. *Recent Social and Economic Trends in India.*

(12) *Census of India*, 1941, **I,** Delhi, 1943.

LAND UTILIZATION, SOIL CONSERVATION AND HUMAN ECOLOGY

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Soil conservation is a problem of human ecology—a problem of establishing a stable society in which human beings are the dominants, and the lesser fauna and flora comprise chiefly domesticated animals and cultivated plants. Such man-dominated communities have existed in the past and exist to-day in equilibrium with their environment over small portions of the earth's surface. Much larger areas are occupied by communities in which man appears as a sort of pseudo-dominant, and which are not in equilibrium with, but are causing the progressive deterioration of, their environment. The problem of soil conservation is to discover and bring into being the conditions in which a stable equilibrium can exist between a human society utilizing the land for its maintenance, and the external environment.

It is a postulate of plant ecology that that plant association becomes the climax—i.e. attains a stable equilibrium with its environment—which can best exploit the environment. Since the climax is in stable equilibrium with the soil it follows that the plant association must give back to the soil as much as it takes from it, i.e. that it is the association which will maintain soil fertility at the highest level of fertility attainable under the prevailing external conditions. It seems reasonable in the light of common experience to extend this principle and to state that a man-dominated society can only supersede a plant-dominated one and attain equilibrium with its environment by raising soil fertility to a higher level than obtains under the natural vegetation.

It is axiomatic that where the environment is deteriorating under human occupation, i.e. where soil fertility is running down, there can be no stable equilibrium, and a continuation of the process must result, if not in man's complete elimination, at least in rendering his existence increasingly precarious.

The invasion by civilized man of a new territory is not gradual, like that of the steppe by the forest, which is scarcely noticeable from year to year and does not disturb the biotic equilibrium, but sudden, like that of a fire. The natural fauna and flora are completely changed over extensive areas within a very short time, and biotic disequilibrium is almost certain to occur. It may not have serious consequences, but often it has. Almost invariably, after the first human occupation of a region, there is a decline of soil fertility which, if prolonged, leads to soil erosion. A human community, like a plant community, has to attain a certain stage of social organization before it can maintain or increase soil fertility. It is the

pioneering stage which is the dangerous period in social evolution. If the environment deteriorates too rapidly the organization of society—its adaptation to the environment—may become impossible. It is for this reason that the planning of land use, which is, in effect, the conscious adaptation of an evolving social organism to its environment, has latterly become a matter of urgency in many parts of the world. Piecemeal, unorganized attempts to control soil erosion or the deterioration of land have not usually met with much success.

The planning of land use is also a problem of human ecology. Indeed, land-use planning and soil conservation are almost synonymous. No long-term plan for utilizing land for the benefit of its occupiers has a chance of succeeding unless it is grounded on the conservation, and preferably the increase, of soil fertility. A living community, whether dominated by man or plant, cannot be stable in a deteriorating environment. The dominance of man, relative to less exacting species, is weakened by a decline in soil fertility and strengthened by an increase. Only in countries of both long settlement and great political stability—as, for example, Britain and Sweden—can the maintenance and increase of soil fertility be regarded in planning land use as secondary to other objectives such as increased production per man hour. In long settled, stable countries the adaptation of land use to the land, accomplished by a long process of trial and error, is fairly complete. Crops, animals and man fit the soil ; farming systems may be modified, usually after overcoming a powerful inertia from a firmly rooted community, in order to accommodate new economic conditions, but the pattern of land utilization remains essentially unchanged.

The purpose of modern land-use planning is to cut out or abbreviate the trial and error process, and consciously to direct the evolution of a man-dominated community towards its climax.

Those who plan must therefore have vision to see not only the crops that will be grown, but also the kind of society that will operate the plan. Mr David Lilienthal, director of the Tennessee Valley Authority, in his book *T.V.A.* emphasized again and again that ' the people must be in on the planning.' The people are as much a part of the plan as the crops and animals they tend, and in general it is only the people who will occupy the land who can plan its utilization in a way that they themselves will carry out. A man probably has greater powers of adapting himself to an unfavourable environment than a plant has, nevertheless it is not to be expected that a pastoralist, and still less a pastoral community, will always be able to adapt himself or itself to arable farming, with benefit to the soil.

A useful, albeit not perfect, criterion of whether a community is adapted to its environment is its state of contentment, which can be judged by its economic prosperity over a period of years or, more accurately, by whether it is able to stand on its own feet under variable economic circumstances. A scheme of land utilization will not succeed unless tangible and lasting social and economic advantages accrue from it. There have been schemes of soil conservation that have been carried through by coercion or with the help of subsidies unsupported by spontaneous co-operation among the occupiers of the land, but they have not succeeded, or, if they have, the results do not give the impression of permanence or stability. Such schemes are only likely to succeed where the planning authority has

sufficient power to treat the human stratum on the same level as the plant strata of the community. In other circumstances the function of the planning authority is mainly to help the people to help themselves.

Examples of highly successful soil conservation carried out by the co-operative efforts of farmers are afforded by certain communal village undertakings in the Punjab, by the anti-erosion works done by tribes in Basutoland, and by the soil-conservation districts in the United States. These all have in common that the work is carried out by the people and for the people with the minimum of coercion from above. Where coercion is necessary, it is a social sanction imposed from within the community.

The American soil-conservation districts are the outstanding examples of land utilization being planned for soil conservation by the occupiers themselves. They have been so successful that they are commonly regarded as the solution of the soil-erosion problem in the United States. The great difficulty is for the Soil Conservation Service to organize them as fast as the demand for them arises. Soil-conservation districts are usually created in areas which have suffered severely from erosion. The state legislature passes an enabling act which gives farmers power to organize and form soil-conservation districts which have the status of governmental sub-divisions of the state. Whether a district is formed rests entirely with the farmers. The powers granted to a district are of two kinds. After it is formed and granted a certificate of organization from the state, farmers then have authority (1) to engage in co-operative action to combat erosion, and (2) to prevent local misuse of land by voting land-use regulations upon themselves. All land-use ordinances must be submitted to a referendum and publicly approved before they can be given effect.

The district is administered by a board of five directors elected from among resident land occupiers, who have power to enforce land-use and soil-conservation measures, but only with the approval of the majority of all the land occupiers, owners and tenants, in the district. A state soil-conservation committee acts in an advisory capacity to give advice and instruction on the best methods for utilizing and cultivating the land, but it has no power to interfere with the working out of the district's plan, which is the concern solely of the farmers themselves.

In planning the utilization of land in a soil-conservation district, the land is classified into eight or fewer classes according to whether it can be safely used for crops, grass or forest, and according to the 'special measures' (e.g. terracing) required to ensure the complete safety of the soil under the proposed utilization. This classification shows the ideal utilization of the land from the point of view of the safety of the soil, but not necessarily from the point of view of the occupiers. The occupiers constitute an economic organism whose continued existence is more important even than that of the soil from which it derives its being. It must go on living, and it must grow in strength. In the soil-conservation district this is recognized by leaving the ultimate determination of land use to the occupiers collectively. It is they who determine the limits beyond which, in the interests of the community, exploitation of the land must not go, and the limits beyond which the existing economic organism must not be strained. They are planning in terms not only of crop ecology, but of human ecology as well. They are adapting the entire living community,

including themselves, to the environment. Herein lies the cause of their dramatic success.

My purpose in describing soil conservation as a problem in human ecology is to suggest that more attention be paid in future studies of land utilization and soil conservation to the adaptation of different types of rural community to different types of land. The mechanics of soil conservation are simple and well known ; the biological principles are less simple, but generally known—e.g. that a high level of fertility and a dense plant cover are sound insurances against erosion. The importance of planting forests on watersheds, of adopting crop rotations, mixed farming, avoiding excessive grazing, cultivating on the contour, etc. is very widely recognized, yet soil continues to be lost on a colossal scale. The necessary measures as a whole cannot be fitted into the existing life of the community. Adaptation of the community must go hand in hand with adaptation of land-use practices, indeed it is questionable whether any distinction should be made between them.

At present we have so little knowledge of human ecology in relation to land that we cannot apply its principles to the practical solution of soil-conservation problems. Yet the example of the soil-conservation districts suggests that if those principles were known they could be applied with equal success elsewhere, and the greater part of the menace of soil erosion would disappear. They were not known in America, but conditions favoured their unconscious application. Adversity compelled the farmers to co-operate. Other means—education, propaganda, subsidies, demonstrations—had been tried to get soil-conservation farming adopted, and had generally failed. Co-operation was tried, and succeeded beyond all expectation. Co-operation developed into the gradual adaptation of the existing human and plant community to the environment. It was, in the main, spontaneous because the people involved possessed a fairly high level of intelligence, and because success breeds success. It is questionable whether the same success would attend similarly organized co-operative soil-conservation projects in Africa. African natives in general have a less clear perception of the meaning of economic disaster and a less close attachment to the land than Americans have. Moreover, the habitats in Africa and America are widely different. Not only will the structure of the ultimate African society be different from the American, but the successional stages between the present and the climax society will also probably be different. It is these which require study and elucidation, so that a leader can start the succession in the right direction and guide it in its later stages. As examples of subjects of human-ecological study that have a bearing on soil conservation may be mentioned the response of primitive societies to economic stimuli, and the effect of indifference to land ownership on land utilization.

A right start in modifying land utilization is all important. If a right start is made and tangible benefits begin to accrue to the land users, subsequent stages should almost look after themselves. Taking the ecological view, the rightness of a soil-conservation measure is judged not necessarily by its immediate effect on the severity of erosion, nor by the number of miles of terraces constructed, but rather by the readiness and spontaneity with which the measure is adopted by the people. A profounder

study of human ecology would allow the social indications of progress towards a biotic equilibrium to be more clearly defined, though perhaps none more definite than the contentment of the community would be found. Sometimes, for example, closure to grazing is accepted and respected by the community as a necessary measure of soil conservation, sometimes it is strongly resisted. Should one conclude that in the latter cases, despite all appearances to the contrary, closure to grazing is not the correct measure to apply in order to reach the desired end ?

'Mixed farming' is sometimes put forward as an almost infallible recipe for soil conservation, probably for the reason that it was dominant at the climax of European civilization in the nineteenth century. It is suggested that a study of human ecology in relation to the soil might reveal other systems of land utilization equally adapted to maintain soil fertility at a high level, and possibly keeping in better step with the social and economic evolution of progressive human societies in different parts of the world.

THE POSITION OF SOIL SURVEY AND LAND CLASSIFICATION IN INDIA

By Professor J. N. MUKHERJEE, C.B.E., D.Sc.

EARLIEST soil studies in India date from Leather (12) and Voelcker (29). A mass of useful information is, however, available in the land settlement records which were begun much earlier. In fact, land has been classified in India for revenue purposes from quite early times, and has been rated according to the crop productivity. Payment in cash instead of in kind seems to have been introduced by Akbar. Experience through ages has determined in areas of old settlements the suitability of the land for the production of crops. Agricultural practices appear to be highly efficient in many areas. Much information of value has been obtained. Textural classification of the soil has been arrived at by empirical methods. Influence of texture, topography, drainage and moisture regime on the productivity of the soil is understood, and is reflected not only in the cropping system of the locality but also on the classification of the land. Schemes of cultural operations and manurial treatments required for different soils and crops have been worked out. The knowledge thus gained is of value for the purposes of soil surveys.

The organization of agricultural research and development on modern scientific lines may be said to have begun with the visit of Voelcker in India during 1889–1891. His report on 'The Improvement of Indian Agriculture' which was published in 1893 is rightly considered to be a useful compilation of information on Indian agriculture at the time. Leather (12) distinguished four major groups of soil: the Indo-Gangetic alluvium; the black cotton or regur soils; red soils lying on metamorphic rocks; and the lateritic soils. The saline soils of the United Provinces, locally called *usar*, also received his attention, and in fact, he carried out some reclamations (13) with gypsum. Such saline soils also occur in other parts of India, e.g., Sind, Punjab, Madras and Bombay. As is to be expected they occur, as a rule, in the arid and semi-arid tracts.

Manurial and water requirements have been estimated from field and pot experiments, the latter having also been initiated by Leather (14). The establishment and development of Departments of Agriculture in the various parts of the country intensified work and extensive data have been collected with reference to the nutrient status of soils, determined mostly by chemical analyses and to mechanical texture. Owing, however, to limitations of facilities and the size of the country, such investigations covered limited regions. Besides, it is only in recent years that it is being realized that the nutrient status of soils with respect to nitrogen, phosphorus and potassium does not constitute permanent features characteristic of soils and that it is necessary to prepare an inventory of the soil resources

of the country on the basis of profile studies. The soils have thus been differentiated and grouped mostly in terms of their contents of the above plant nutrients and soil maps have been prepared showing these contents.

The relation between the broad soil zones in India and the basic geological formation has been discussed by Wadia, Krishnan and Mukherji (30) based on the work of various members of the Geological Survey of India. They have pointed out that the 'black cotton' soils or 'regur' generally occurs on basaltic trap formations, and the red soils on granites, gneisses and sandstones. In India, vast stretches of soils occur on alluvium, the term being used in a geological sense. The above workers differentiate the alluvium into two types, older (bhangar) and the newer (khada) based on the degree of metamorphism which has produced changes in colour, etc.

From the point of view of vegetation, Troup (27) recognized ten different geographical forest regions in India; Champion (4) divided the soils of India and Burma into fifteen climatic types and prepared a map showing their distribution. Maps showing the distribution of crops are also available. On the basis of climatic variations, i.e., temperature and rainfall, India has been divided into a number of zones (11). Raman and Satukopan (20) characterized the climates of different regions of India using as an index the annual rainfall less annual evaporation. Basu (2) pointed out that soils of India show certain differences in different zones divided on the basis of Lang's factor. Hosking (8) employed Meyer's N—S coefficient in his studies on the relationship between the black earths of Australia and the black soils of India. Viswanath and Ukil (28) have attempted to place the soils of India within different climatic zones defined by the same coefficient. An integrated study of the effect of climate, vegetation and topography on the formation of soil has not yet been attempted so far on the required scale.

Soil studies based on profile examinations on which modern soil surveys are based have attracted attention, only recently, in India. In the following a brief account has been given of soil studies from this point of view.

Soil zones in India

It is not difficult to recognize a number of soil zones in India although their characteristics have not yet been well-defined. Based on climate, colour, nature of the underlying geological formation and other features, the following broad soil divisions are recognized by soil workers in India.

Black soils which include 'regur,' i.e., black soils considered to be suitable for cotton. These soils extend over the greater part of the Bombay Province and also Kathiawar, Berar, the western parts of the Central Provinces, Central Indian States and Hyderbad and some parts of the Madras Presidency.

Profile features of the black soils have been examined amongst others by Ramiah (21), Basu (3) and Bal (1). The main features of the black soils are: the depth varies from one or two feet to more than twenty feet; texture varies from loam to clay; heavy cracks appear in the dry summer, which in heavy clays may be three to four feet deep; presence of lime nodules at some depth, and apart from these, free carbonates, mostly calcium carbonate, are often present mixed with the soil. These soils are

generally rich in montmorillonitic and beidellitic groups of clay minerals. In a large proportion of these soils gypsum is present.

The investigations of Basu and Sirur (3) have distinguished as many as twelve types of black soils in the Deccan canal areas based on profile examination and laboratory analyses. These types have been classified into two major groups of soils depending on the conditions of their development under restricted or free drainage. In the former soluble salts are present in varying amounts throughout the profile ; the soils are cloddy and show a high degree of sodium saturation. The latter is base-saturated, and possesses a granular or crumb structure. Free carbonates of lime are present in both.

Red soils. This division possibly includes red loams, red earths and yellow earths. Characteristic features of the profiles of a number of red soils have been examined (22, 23). These soils occur extensively in Madras, Mysore, south-east Bombay, eastern part of Hyderabad State, Central Provinces, Orissa and Chota Nagpur. The red soils extend northwards and eastward of the above tracts and include the greater part of the Santhal Parganas, western Bengal, the Mirzapur, Jhansi and Hamirpur districts of the United Provinces, the Baghelkhand Agency of Central India, the Aravallis and the eastern half of Rajputana. The clay fractions of the red soils are rich in kaolinitic types of mineral. They are generally light in texture, porous and friable ; lime 'kankar,' free carbonates and soluble salts are generally absent.

Laterite and lateritic soils. The expression 'lateritic soil' is used rather loosely. Red, brown and yellow soils are often described as lateritic soils. It has been suggested (22, 23) that the term 'lateritic soil' should be restricted to those soils in the profiles of which honeycomb laterite rocks are actually present. Laterites in the sense in which this expression was originally used by Buchanan and lateritic soils as defined above have been reported (22, 23) to occur in Malabar, south Bombay, the Deccan, Central India, Central Provinces, Rajmahal, parts of Assam and the eastern Ghat regions of Orissa. In the higher altitudes, usually 2,000 ft, such soils are thin and gravelly. In the lower altitudes and in the valleys they occur as dark heavy loams or clays.

Alluvial soils. The so-called alluvial soils cover a wide range of climatic and topographical and drainage conditions. There classification from the point of view of soil science remains to be determined by further studies. Soils on Bhangar (old alluvium) and Khadar (new alluvium, *loc. cit.*) are distributed mainly in northern, north-western and north-eastern parts of India in Sind, Punjab, United Provinces, Bihar, Bengal, parts of Assam and Orissa. Apart from these soils on 'old' and 'new' alluvium of the geologists, soils formed by recent alluvial deposits of river-borne material are also often described as alluvial soils. In the coastal areas of southern India, including the deltaic areas at the mouths of the rivers, occur soils on recent deposits of river-borne materials. From the agricultural point of view all of these alluvial soils are most important and most fertile amongst Indian soils. Surveys of soils on a profile basis on the Indo-Gangetic alluvium are in progress in the Punjab (5) and in the United Provinces (18).

A survey of soils on recent deposits of river-borne materials has been

worked out in a small area in the coastal region on southern Bengal. A clay pan has been observed in many of these soils (19). A large accumulation of fine materials, particularly clay, a high percentage of alumina, low contents of lime and air pore space, a compact consistency and a prismatic structure, are the special features of the pan horizon.

Forest soils. Two conditions of soil formation have been distinguished in the forest regions : (*a*) soils formed under acid conditions with the presence of acid humus and low base status favourable for podsolization (7, 26), and (*b*) soils formed under slightly acid or neutral conditions with high base status which are favourable for the formation of brown forest soils (16, 17). It has been reported that red loams, brown forest soils, and podsols occur in the Kumaun Hills. However, systematic studies on forest soils remain to be undertaken in order to determine their characteristics and classification as fourteen per cent of the total land area of India is under forests.

Soils occurring in arid and semi-arid regions. Desert soils cover the major portion of Sind and also occur in Rajputana and South Punjab. The Thar or the Rajputana desert alone occupies an area of 40,000 square miles. The desert soils of Sind contain high percentages of soluble salts ; show high pH values and low loss on ignition, and are poor in organic matter. Calcium carbonate occurs in varying amounts. The limiting factor being mainly water, irrigation facilities are being extended. Pre-irrigation surveys have been undertaken. Many parts of the arid and semi-arid tracts of Bihar, United Provinces, Punjab, Rajputana and Sind show saline and alkaline efflorescences on the surface which are locally known as *reh*, *kallar*, *usar* and *thur*.

Peaty and marshy soils. Peaty soils occur in some of the humid regions. They have also been reported in depressions formed by dried river basins and lakes in some of the alluvial coastal regions. In addition to organic matter, considerable amounts of soluble salts are also present. Such peaty saline soils (*kari*), have been observed in Travancore and in Cochin. The ' Kasch ' soils of Chittagong in Bengal probably belong to this type and are generally blue-coloured due to the presence of ferrous iron. Marshy soils (*bheel* soils) are found in Sylhet, in Assam, in coastal tracts of Orissa, in the Sunderbans and other places in Bengal, in the Central portion of North Bihar, in the Almora district of the United Provinces and in the south-east coast of Madras.

Soil surveys in relation to irrigation

Soil surveys in connexion with irrigation projects have been carried out in Madras, Punjab, Sind, Bombay, Mysore and Hyderabad.

Investigations by Ramiah (21) in connexion with the Tungabhadra project in Madras showed that heavy black soils found in the area commanded by the project could be safely irrigated and that no danger was likely to ensue from salts or water-logging. The soil is of the heavy black type and quite deep but the concretionary layer in the deeper subsoil is porous. The soil survey in connexion with the Gundlakama irrigation project showed that the soils are mostly of the deep black heavy type with appreciable salt content but irrigation was considered to be possible if adequate drainage could be provided.

From surveys in relation to irrigation in the Bombay Deccan, the soils have been classified into four subdivisions based mainly on drainage conditions. Out of the total area of 75,000 acres irrigated, one-third has been damaged owing to water-logging and the remaining two-thirds are more or less affected by salts. Reclamation measures based on pipe drainage and treatment with gypsum have been taken up (24).

The land reclamation section of the Punjab has been conducting a number of pre-irrigation and post-irrigation soil surveys in several areas. It has been estimated that in the Punjab over half a million acres have been abandoned as unfit for cultivation owing to accumulation of salt and it is estimated that nearly 25,000 acres are being added to this figure each year (9, 25). A negative correlation between the degree of saturation with sodium and the crop yield has been observed. In Sind, the salt and texture profiles are being examined extensively in the areas to be put under irrigation.

In the Nizam Sagar project in Hyderabad 275,000 acres out of a total of 500,000 acres are expected to be irrigated, the area already under irrigation being 70,000 acres. A soil survey has also been carried out in relation to the Tungabhadra irrigation project in Hyderabad, and it covers an area of about 2,700 square miles. The soils have been graded according to their suitability for rice cultivation and four types have been distinguished (15).

In the Mysore State four soil surveys in connexion with irrigation projects have been carried out. These are: (*a*) the Irwin Canal soil survey, (*b*) the French Rock soil survey, (*c*) the Shimsa project survey in Mandya district and (*d*) the Vani-vilas soil survey in Chitaldrug district. The first was a pre-irrigation and the second and fourth post-irrigation surveys and the third was simply a traverse survey. The areas commanded by the Irwin Canal and the Vani-vilas Sagar are respectively 120,000 and 100,000 acres. The water of the Irwin canal is utilized also for the French rock area.

While saline soils ('solonchak') and alkaline soils ('solonetz') have been observed in the irrigated tracts, the degraded alkali or 'solodi' soil has been rarely found in India. Calcium carbonate is mostly present in these soils.

Soil erosion and soil conservation

Erosion has considerably affected the productivity of large areas. Striking examples of soil erosion are to be found in the hill tracts in Bundelkhand, the Punjab, the North West Frontier Province, Baluchistan and in many other places. Erosion and sand deposition by rivers have caused and are continuing to do great loss of and damage to soil in parts of Central Provinces, Bihar, Assam and Bengal. Wind erosion has also been responsible for the loss of valuable top soils in many areas. Thus, in the Indus valley recent disforestation in the Thal has resulted in the removal of the top soil. On the sea coast of Kanara, Malabar, Puri and Coromandel the wind-driven sand shows a tendency to advance inland. Its progress is being checked by plantations in some areas. Important soil conservation measures are in progress in the Punjab and Bombay (6).

A start has recently been made in the Bombay Presidency to study the

correlation between the intensity of rainfall and slope on the one hand and erosion on the other with a view to ascertaining the type of land use for which the soils are best suited. Measures such as bunding, strip-cropping and afforestation are intended to be adopted on the basis of such studies. The most suitable methods for the conservation and utilization of soil moisture are being evolved (10).

The existing data on Indian soils have been collated in the Final Report of the All India Soil Survey Scheme which was financed by the Imperial Council of Agricultural Research. A map of India showing general distribution of soils, which has been prepared on the basis of the existing soil data, is included in the Report.

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References

(1) Bal, D. V. 1935. Some aspects of the black cotton soil of Central Provinces and Berar. *Emp. J. Exp. Agric.*, **3** (No. 11), 261–268.

(2) Basu, J. K. 1937. A review and appreciation of soil survey work in India up to date with suggestions for the future. *Proc. 2nd Meeting Crops and Soils Wing, Board of Agriculture and Animal Husbandry in India*, 226–240.

(3) Basu, J. K. and Sirur, S. S. 1938. Soils of the Deccan Canals I. Genetic Soil Survey and Soil Classification. Nira left bank and Pravara Canal. *Indian J. Agric. Sci.*, **8**, 637–697.

(4) Champion, H. S. 1936. A preliminary survey of the forest tree of India and Burma. *Indian For. Rec.*, New Series, Silviculture, **1**, No. 1.

(5) Dalip Singh. Unpublished work.

(6) Glover, H. 1944. *Soil Erosion.* Oxford Pamphlets on Indian Affairs, No. 23.

(7) Hoon, R. C. 1938. A study of the soils in the hill areas of Kashmir. *Indian For. Rec.*, Silviculture, **1**, 347–368.

(8) Hosking, J. S. 1937. *Curr. Sci.*, **5**, 422.

(9) Kadam, B. S. 1935. Note on Thar or Kallar lands in the Punjab. Proc. Crop sand Soils Wing of the Board of Agriculture and Animal Husbandry in India.

(10) Kanitkar, N. V. 1944. *Dry Farming in India.* Imperial Council of Agricultural Research.

(11) Kendrew, W. J. 1944. *The climate of the continent.* Oxford University Press.

(12) Leather, J. W. 1898. Soils. *The Agricultural Ledger*, No. 2 (Agricultural Series, No. 24).

(13) Leather, J. W. 1897. Reclamation of Reh or Usar lands. *The Agricultural Ledger*, Nos. 7, 13.

(14) Leather, J. W. 1906. *Mem. Dep. Agric. India, Chem.*, Series No. 1.

(15) Mehta, J. M. 1933. Report on the Agricultural Survey, Tungabhadra Project, Raichur District (Hyderabad—Deccan).

(16) Mukherji, B. K. and Das, N. K. 1940. Studies on Kumaun Hill Soils. I. Soil Survey at the Government Orchards, Chaubattia Formation of Genetic Groups. *Indian J. Agric. Sci.*, **10,** 990–1020.
(17) Mukherji, B. K. and Das, N. K. 1941. Studies on Kumaun Hill Soils. II. Effect of terracing and cultivation on soil types at Chaubattia. *Indian J. Agric. Sci.*, **11,** 941–953.
(18) Mukherji, B. K. *et al.* Unpublished work.
(19) Mukherjee, J. N. Annual Reports of the working of the Scheme of research into problems relating to coastal soils. 1939–1944. Imperial Council of Agricultural Research.
(20) Raman, P. K. and Satukopan, V. 1935. *Sci. Notes Met. Dep. India,* **6,** No. 61.
(21) Ramiah, P. V. 1937. A Report on the Soil Survey of the Tungabhadra Project Area. Print. Supdt. Govt. Pres. Madras.
(22) Raychaudhuri, S. P. 1941. Studies on Indian Red Soils III, General Morphological characteristics of some profiles. *Indian J. Agric. Sci.*, **11**, 220–235.
(23) Sen, A. T. and Deb, B. C. 1941. Studies on Indian Red Soils II. *Indian J. Agric. Sci.*, **11**, 617–629.
(24) Talati, R. P. 1941. Damaged lands in the Deccan and their classification. *Indian J. Agric. Sci.*, **11,** 959–977.
(25) Taylor, M., Puri, A. N. and Asghar, A. S. 1934. Punjab Irrigation Research Institute Pub., 1934, **IV,** Part VII.
(26) Taylor, E. McKenzie, Mahendra, I. D., Mehta, M. L. and Hoon, R. C. 1935. An investigation of soil profiles under Deodar, Spruce, Blue pine and Chir. *Indian For. Rec.*, New Series, Silviculture, **1,** 289–346.
(27) Troup, R. S. 1921. *Silviculture of Indian Trees,* **1,** 17.
(28) Viswanath, B. and Ukil, A. C. 1944. Comparative studies on Indian soils I. Regional and Environmental Factors associated with Indian soils. *Indian J. Agric. Sci.*, **14,** 333–344.
(29) Voelcker, T. A. 1893. *The Improvement of Indian Agriculture.*
(30) Wadia, D. N., Krishnan, M. S. and Mukerjee, P. N. 1935. Introductory note on the Geological Foundations of the soils of India. *Rec. geol. Surv. India,* **68,** 363–391.

THE PRODUCTIVITY OF INDIAN SOILS IN RELATION TO FOOD SUPPLY

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Food shortage in India has come to be known very widely because of a recent famine and the demand for help on the Combined Food Board of the United Nations Organization.

Some aspects of this problem relating to the productivity of the soil are examined below.

A. AREA AVAILABLE FOR CROP PRODUCTION

1. Although statistics in India cannot be said to be very reliable, the available land area which can be used for agricultural purposes, excluding forest areas, may be taken to be as follows[1] :—

	million acres
net area sown	282
current fallows	59
cultivable waste other than fallow . .	111
total .	451

The figures given above do not include the area for which returns do not exist. The area under more than one crop in the same year is about 35 million acres.

The area under forests is estimated to be 87 million acres.

2. The population is just over 400 millions[2] and the acreage of sown areas works out at 0·72 per capita. A not yet determined part of the area shown as cultivable waste other than fallow, and current fallow, is not suitable for immediate utilization. Attempts are being made to ascertain their suitability for different types of land use with special reference to agricultural production. Even if these areas be included in our estimate of the total land available for cultivation, the potential land per capita is 1·12 acres. Of the total of 282 million acres under cultivation, commercial crops like jute, cotton, tea and others occupy an area of about 30 million acres.[1] Some of these areas are used for a second crop which is generally a food crop, but lack of data does not enable us to arrive at any useful estimate.

3. It is also to be considered that the population is increasing at the rate of nearly 5 millions[2] a year, and with better sanitation and medical remedies this rate of increase may continue for some time. If however the level of

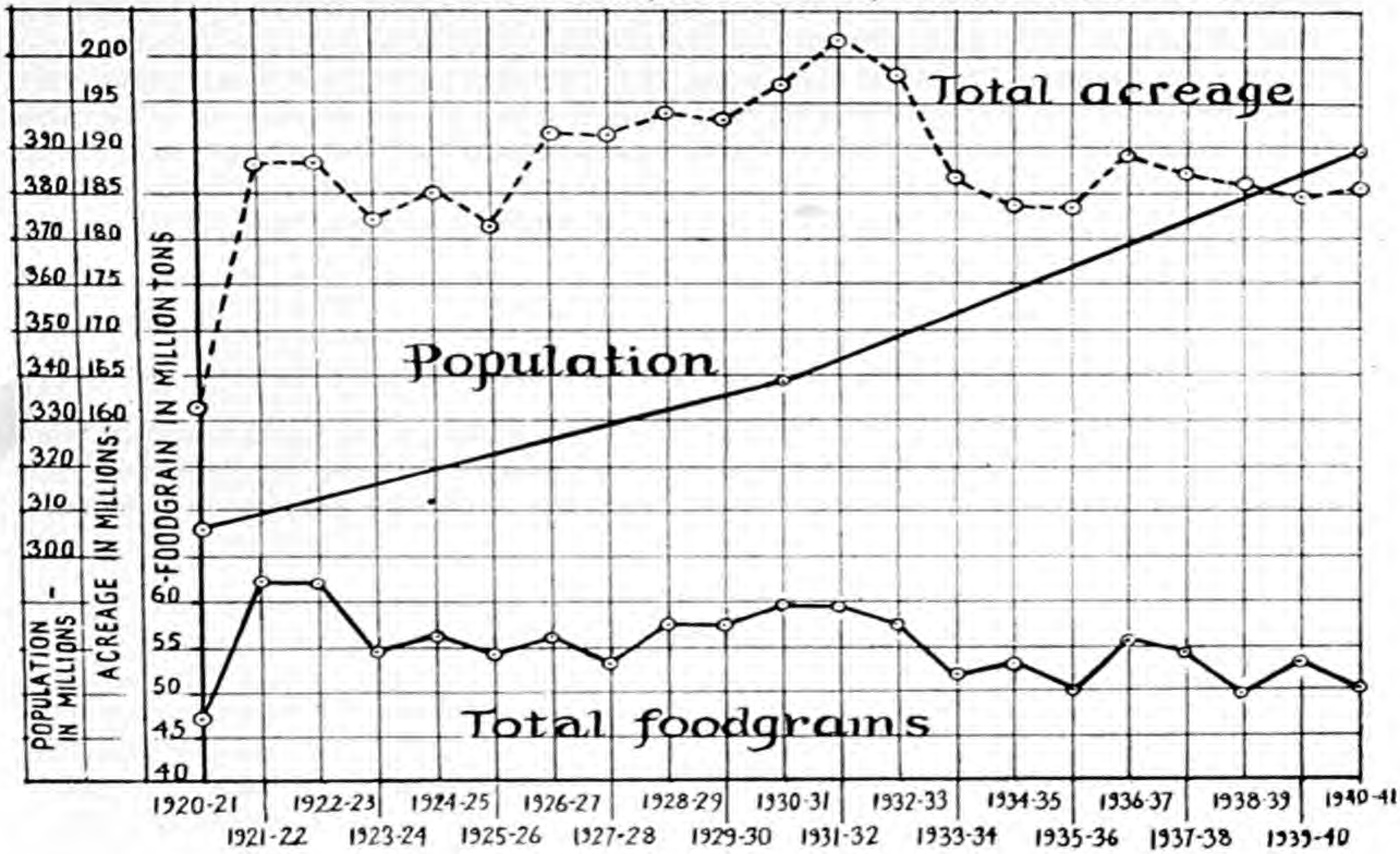
amenities is raised amongst the masses of the population, and with better education, the same factors which have operated in other countries for the limitation of birth-rates are likely to decrease the annual growth of population in India.

4. The effect of the increase of population on the food situation is illustrated below.

B. REQUIREMENTS OF CEREALS FOR FOOD

5. Various estimates have been made of the food requirements of India. Food habits have been determined partly by local availability, partly by the purchasing power of the people and partly by other factors. Without

POPULATION, TOTAL ACREAGE AND TOTAL PRODUCTION OF MAJOR FOODGRAINS (RICE WHEAT, JOWAR, MAIZE & GRAM) IN INDIA-1920-21 TO 1940-41



considering these in detail, it is not possible to make any valid estimate of the food requirements of India as a whole. Food habits are likely to continue to be influenced by conditions of availability for some time to come, but knowledge of what constitutes a more balanced diet is likely to affect them. For our present purpose, however, we may take the following figures as a rough guide. Taking 1 lb. as an over-all average of food grains per capita per day as the normal requirement, the present population requires 67 million tons of grain for purposes of food alone. To this has

to be added the annual loss estimated [3] to be 3·5 million tons due to unsatisfactory storage conditions. The seed requirement of the country at the rate of 4 per cent of the total production will amount roughly to 2·5 million tons. With the present estimated average production of 60 million tons of food grain, India faces an annual deficit of 12·7 million tons. With the present rate of increase, the population after ten years will reach 460 millions, for whom 75 million tons will be required for food. Adding 3 million tons for seed purposes, and assuming that improvement of storage conditions will limit the spoilage to 3 millions, the total requirement will stand at 81 million tons; that is, the additional quantity of cereals required to be produced may be roughly estimated to be 21 million tons, if India has to avoid famine or dependence on other countries for her normal food requirements. The above figures do not deal with potatoes and other tubers which are used as a source of carbohydrate for food. The present production of potatoes is roughly estimated to be 1·8 million tons [4] of the fresh material, and account has to be taken of its much larger moisture content. Spoilage, however, is considerable under the present conditions.

No allowance has been made in the above estimates for the demands of industry on cereals. Similar deficiencies in production have been estimated as regards sources of protein and fat, which have to be mostly of vegetable origin under present day conditions of Indian food habits. Apart from fish, for the supply of which there is considerable scope for development, increased production of protein and fat of animal origin also involves the utilization of land.

C. YIELDS PER ACRE OF PRINCIPAL CROPS

6. It is apparent that the productivity of land is of fundamental importance. The Royal Commission on Agriculture in India pointed out the low productivity of Indian soils and its gradual decline. Table 1 illustrates the position.

TABLE 1

yield per acre in lb [5]

year	wheat	rice
1895–96 to 1899–1900	596	943
1900–01 to 1904–05	694	961
1905–06 to 1909–10	683	880
1910–11 to 1914–15	708	903
1915–16 to 1919–20	683	900
1920–21 to 1924–25	683	847
1925–26 to 1929–30	632	836
1930–31 to 1934–35	620	851
1935–36 to 1939–40	661	786
1940–41	643	679
1941–42	664	773
1942–43	718	743
1943–44	642	847

7. The following figures[4] show the gradual decline of the acreage per capita of land under food crops.

TABLE 2

acreage of land per capita in British India

year	population (millions)	net area sown (million acres)	acre per capita	area under food crops (million acres)	acre per capita	area under food grains (million acres)	acre per capita
1910–11	231·6	223	0·96	214	0·92	204	0·88
1920–21	233·6	212	0·90	197	0·88	187	0·84
1930–31	256·8	229	0·89	214	0·83	203	0·79
1940–41	295·8	214	0·73	198	0·67	187	0·66

TABLE 3

yield per acre in lb[5]

year	sugarcane	cotton ginned
1914–15	23,690	85
1919–20	25,320	99
1924–25	22,520	91
1929–30	24,530	81
1934–35	33,080	81
1939–40	28,680	91
1940–41	28,290	101
1941–42	28,090	102
1942–43	31,580	97
1943–44	31,020	99

8. It is interesting to note from table 3 that while the yield per acre of wheat and paddy, in spite of increasing acreage under irrigation and better varieties, has not increased, and seems to have decreased, that of sugarcane and cotton shows an upward trend. This difference cannot be attributed to any special defect in the collection of statistics for paddy and wheat. Cotton and sugarcane are, however, money crops and organized industries are behind them. Also sugarcane is cultivated to a larger extent under irrigated conditions.

9. It seems, therefore, that there are special factors limiting the yield of paddy and wheat, not operative in the other cases. The cereal crops are almost entirely the concern of the poor peasant, who has to depend on his traditional methods and is unable, in the vast majority of cases, to provide adequately for manures and fertilizers, water and timely cultural operations, even to the extent that he is aware of their usefulness.

10. Reference has been made above to the low productivity of Indian soils. The following tables give a comparative statement of the yield per acre of the principal crops in India and some other countries.

TABLE 4

yield per acre of principal crops in India and some other countries (average of a number of years)

country	rice [7]	wheat [6]	cotton [6]	sugarcane [6]
	lb	lb	lb	lb
India . .	700–900	650	90	28,700
U.S.A. .	1,450	850	190	41,481
Egypt . .	2,000	1,800	450	58,240
Italy . .	3,000	1,150	—	—
China . .	1,400	989	—	—
Japan . .	2,300	1,350	200	—
Java . .	1,350	—	—	98,400–114,800

TABLE 5

yield per acre in the United States of America [8]

year	rice	wheat	cotton
	lb	lb	lb
1896	869	768	165
1906	1,474	960	202
1916	2,111	714	165
1926	1,863	882	192
1936	2,286	768	199
1939	2,264	846	237

TABLE 6

wheat yields per acre in lb [8]

country	1925–29	1930–34	1937–39
United Kingdom . .	2,166	2,292	2,366
Australia	636	732	794
New Zealand . .	2,034	1,812	1,898
Germany	1,754	1,926	2,227
Italy	1,140	1,248	1,413
Egypt	1,548	1,656	1,916
Japan	1,518	1,626	1,746
Argentina	768	828	894
India	632	620	661

D. FACTORS INFLUENCING PRODUCTIVITY

IRRIGATION

11. Water is the most important single factor limiting production of agricultural crops in India, and attention has naturally been paid to increasing facilities for irrigation. The progress made in this respect is illustrated in the following table :—

TABLE 7

area under irrigation in acres, 1910–11 to 1935–36 [1]

year	government canals	private canals	tanks	wells	other sources	total
1910–11	17,841,139	2,280,854	6,860,804	11,539,277	7,286,494	45,798,568
1915–16	20,167,509	2,830,154	6,080,009	13,807,231	7,638,084	51,956,240
1920–21	21,958,515	3,164,313	8,277,870	16,245,483	6,283,129	55,928,410
1925–26	22,198,579	4,554,950	7,025,089	13,702,007	6,819,240	54,299,965
1930–31	24,660,132	4,413,452	8,144,283	14,160,115	6,702,386	58,080,368
1935–36	26,657,818	4,597,579	7,616,085	15,282,609	5,747,440	59,905,686

12. The figures for the area shown under government canals are more reliable ; those under other heads are not equally so and the supply from the latter is not infrequently precarious. Over the greater part of India non-irrigated crops depend upon the precipitation from the South-West Monsoon, which unfortunately is concentrated between July and September. The average annual rainfall varies widely from below 10 inches to above 250 inches, and in certain areas, e.g. in Cherrapunji, it exceeds 450 inches.

13. There are vast stretches of arid and semi-arid lands where the increase of yield expected from irrigation is large indeed. Quite a large number of rivers have not yet been harnessed either for hydro-electric power or for water for irrigation. Without any detailed survey, it is not possible to give an estimate of the ultimate area which can be irrigated with river water. Harnessing of rivers will also prevent the present loss of soils and of crops from extensive floods. The Damodar Valley project, which aims at the utilization of the waters of a not unusually large river, is expected to provide irrigation for 750,000 acres. For the purpose of preparing comprehensive and integrated water plans for the various river basins in India, the Government of India have set up the Central Waterways, Irrigation, and Navigation Commission to deal with the problems of flood control, soil erosion, drainage and land-reclamation, irrigation and navigation. It will conduct surveys and investigations with a view to securing planned utilization of India's surface and sub-soil water resources and press forward schemes for the conservation, control and regulation of water and waterways in consultation with Provincial and State Governments. Large water projects costing over 125 crores of rupees (£93 million) are ready for execution in some of the provinces and states.[9]

14. Availability of manures and fertilizers even where irrigation facilities are obtainable has stood in the way of better utilization of water. In spite of these and other limitations, the increased yield from irrigation which has been obtained is illustrated in table 8.

TABLE 8

average yield of rice and wheat (in lb) under irrigated and non-irrigated areas from 1901–1936 [3]

province	rice		wheat	
	irrigated	non-irrigated	irrigated	non-irrigated
Madras .	1,100	800	—	—
Bombay .	—	1,200	1,250	510
Sind . .	1,300	—	1,050	750
U.P. . .	1,070	850	1,200	800
Punjab .	900	650	950	600
N.W.F.P. .	1,030	—	800	530

15. The figures for the yield of rainfed rice, i.e., under non-irrigated conditions in Bombay, are interesting. It will be seen that the yield is almost the same as that under irrigated conditions. This is due to the fact that in Bombay rice is mostly grown in a tract where rainfall is copious, i.e., over 100 inches. It perhaps also shows that the benefit of irrigation has so far been derived from the application of water alone and does not represent the increased yield which could be obtained if fertilizers and manures were applied as they should be, and other conditions influencing the yield were also attended to on a high level of efficiency.

16. That irrigation coupled with adequate use of manures and fertilizers and attention to other limiting factors can raise the productivity of the soil to a much higher level than that indicated in the above figures, is borne out by many observations. A brief reference to this will be made later.

17. Irrigation, however, has not been an unmixed blessing. The importance of pre-irrigation soil surveys has only been realized rather recently. In the Punjab alone, more than half a million acres have been affected more or less by saline conditions and waterlogging. In the semi-arid tracts of India, salinity of the soil constitutes a danger. In the United Provinces, a rough estimate shows that about 2 million acres are more or less affected by salts. Besides, for want of adequate provision of reservoirs and sometimes not very efficient distributory systems, the water available in the existing irrigation systems is not always used to the best advantage Perennial irrigation is comparatively rare. The importance

of drainage of irrigated lands is only lately being given the emphasis that it deserves.

18. Apart from rivers other sources of water have been used in India for a long time for purposes of irrigation. A journey by air from Delhi to Calcutta shows how densely the land in Western Bengal is studded with tanks. These tanks also collect the silt brought into them by sheet erosion and the value of the silt for improving the productivity of the soil is recognized, it being the custom to desilt the tanks and put the silt on to arable lands. Loss by evaporation from tanks is often minimized by the practice of planting trees on the dams surrounding them. Irrigation from bunds, i.e., water impounded in sloping lands by artificial soil dams, is practised in many parts of the country. Well irrigation is another form which is used extensively in many parts of the country. More or less stagnant pools, specially in former river beds, constitute another source in some parts of the country. One of the factors of immediate relief to the problem of water supply is the provision of suitable pumps for lifting the water from tanks, bunds, wells and stagnant pools. The usual age-old methods are time consuming and lead to loss by seepage.

19. Perennial irrigation is possible in many areas if lift-irrigation could be utilized to supplement the supply from gravitational irrigational systems when water from the latter is not available. A rapid survey of the sources of water supply for purposes of irrigation is likely to give some immediate relief in certain parts of the country. A thorough hydrological survey of underground water resources is no less important. Although recently attention is being paid to irrigation from sub-soil water which is promising of results, the need for a thorough survey of surface and underground water resources cannot be over-emphasized and it should be taken up immediately and intensively. Quite a number of diseases in India result from the unsound quality of the potable water, and underground sources have already ameliorated conditions in some areas. Most of the tube-wells which are still, comparatively speaking, few in number, do not go beyond a depth of 200 to 400 ft. There is no reason why systematic borings should not be carried out to locate sources of underground water supply. Australian experience in this field is likely to be of use to India. Underground sources may relieve the demand for water for irrigation by providing water for industrial and other purposes, if need be, by suitable treatment.

Manures and fertilizers

20. The value of manures and fertilizers is not unknown to Indian peasantry. Availability, cost, and detailed information regarding dosage and combinations of plant nutrients which will preserve and build up fertility, are the factors which stand in the way of their more extensive use. Much has been written on the loss by burning as fuel of potential farmyard manure. Village forests and judicious distribution of quick-growing trees, development of cheap hydro-electric power in areas where this is possible, better methods of utilization of coal, all have possibilities for remedying the situation. The following figures of fertilizer consumption in India when considered in the light of the acreage under crops (282 million acres) will reveal the second major factor limiting crop production:

TABLE 9*

fertilizer consumption in India (in tons), 1944–45 [10]

	imported	manufactured	total
sulphate of ammonia .	50,841	20,000	70,841
muriate of potash .	597	—	597
superphosphate . .	1,592	2,000	3,592
other phosphates .	1,500	—	1,500
ammonium phosphate .	14,000 (approx.)	—	14,000 (approx.)
fish maunre . .	2,452	—	2,452
total . . .	70,982	22,000	92,982

21. The fertilizer consumption in the United States of America with 338 million acres under crops and fruits was 8·8 million tons in 1942.[8] Depletion of plant nutrients has continued for ages and productivity of the soil in India is now determined by a minimum level of fertility which unaided natural processes can maintain. Judicious use of fertilizers in irrigated tracts is most likely to yield immediate results. Experiments on fertilizers have been restricted in number and scope through limitations of facilities for them. Continued experiments, especially with mixed or complete fertilizers, have been rather conspicuous by their absence. Studies on placement of fertilizers even where it should be possible to use mechanized methods, do not seem to have received any attention. And the same remark is applicable to the different forms of the major plant nutrients. Attention has been paid only recently to the importance of trace elements. Still less attention has been paid to systematic studies on fodder. This unhappy situation is, however, likely to change much for the better, as all these aspects have begun to receive attention by the agricultural research organizations which it is hoped will rapidly grow in number and be provided with greater facilities.

22. Although it has not been possible so far to pay sufficient attention to the above aspects mostly for want of adequate facilities for study, results of considerable utility have already been achieved by the Provincial and State Departments of Agriculture and through the schemes of research and development initiated and financed by the Imperial Council of Agricultural Research. To take two crops like wheat and paddy such results have shown the possibility of increasing the yield to 2,500 lb of wheat and 3,500 lb of paddy per acre. Similarly, a yield of 50 tons of sugarcane per acre has been achieved by attention to all factors including the variety of the crop. A large scale trial with paddy on 27 acres of channel irrigated private land in Mysore has demonstrated that by judicious manuring the fertility can be increased to a very high degree. A mixture of oilcake and superphosphate (the latter being replaced in later years by bonemeal and

* Does not include bones and oilcakes.

calcined tricalcic phosphate) supplying 12 lb of nitrogen and 18 lb of phosphoric acid per acre, and 1 to $1\frac{1}{2}$ tons of cattle manure were used. It will be seen from the yield figures in the following table that between the period 1928–29 and 1939–40 the increase is about 456 lb per acre, whereas between 1939–40 and 1943–44 it is 236 lb per acre. In fact during the last three years the yield is almost steady and perhaps represents the maximum the soil is capable of producing under the prevailing conditions.

TABLE 10

yield of paddy in lb per acre [11]

season	maximum	minimum	average for the area
1924–25 . . .	1,953	828	1,480
1925–26 . . .	2,111	857	1,663
1926–27 . . .	2,137	1,145	1,735
1927–28 . . .	2,916	1,901	2,281
1928–29 . . .	3,078	1,962	2,466
1939–40 . . .	3,746	2,426	2,950
1940–41 . . .	3,510	2,277	2,776
1941–42 . . .	4,077	2,538	3,071
1942–43 . . .	4,133	2,599	3,148
1943–44 . . .	4,133	2,673	3,186

Crop rotation

23. The traditional cropping systems in India sometimes include a legume or a crop for use as green manure in a rotation. But the cropping system is more often than not determined by the exigencies of the situation from the point of view of subsistence farming. The usefulness of the inclusion of a legume in the rotation has been proved in a number of cases. In the Punjab Berseem (Egyptian clover) and some other legumes have found favour with some peasants. The question of systematic studies of legumes and of their introduction is at present receiving some attention. Seeds of clover from different countries have been brought, and very recently experiments have been taken up with kudzu and lespedeza. With more reliable and extensive experimental data and adequate propaganda with a view to enlisting the willing co-operation of the peasant, great improvements in soil fertility may be expected to result from the judicious use of crop rotations coupled with the use of manures and fertilizers. Animal husbandry as an industry is perhaps in a still more backward condition, and there is immense scope for the development of the use of legumes and grasses (and other types of fodder), not only with a view to placing this industry on a firm footing but also as a measure for improving soil fertility and controlling erosion. Although some useful results have

already been obtained and some of them have been utilized by the peasants, the fact remains that the use of legumes being very limited their effect on the general level of productivity of the soil has not yet been marked. Investigations with indigenous and exotic leguminous plants and grasses with a view to testing their suitability for different purposes, it is hoped, will soon be intensively taken up.

Conservation of moisture

24. In areas where either the rainfall is deficient or irrigation is not available, conservation of moisture naturally assumes a great importance. Even in areas where the monsoon rainfall is considerable, the conservation of moisture is of great importance for crops grown after the monsoon. Besides, the vagaries of the weather require attention to the conservation of moisture as also to drainage. A number of schemes with a view to ascertaining the best ways of conserving moisture have been worked out in different parts of the country under conditions commonly known as 'dry farming.' These have yielded promising results, and in certain parts, e.g., in Bombay Presidency, applications of improved methods are being initiated on a fair scale.

Drainage

25. Apart from the question of waterlogged soils in irrigated areas to which a brief reference has already been made, drainage of soils seems to deserve much greater attention. Reclamation of swamps and waterlogged areas by drainage should be possible in many areas. But a careful survey requires to be made as some of these areas could be better developed either as fisheries or for recreation and preservation of wild life.

26. In some areas where a single crop of paddy is taken from the soil in a year, the question of drainage seems to deserve close attention. In extensive areas, e.g. in Bengal, Assam, Orissa, whether one, two or three crops are taken depends on the conditions of topography and drainage of the land. Drainage of the comparatively speaking low-lying areas which yield only one crop under existing conditions, is likely to enable another crop being taken.

Tillage and other cultural operations

27. In India three types of primary tillage are in operation, viz. soil stirring, soil paring and soil inversion. The principle of the Indian plough consists in essentially soil stirring. Soil paring in which the soil surface is scraped or undercut in a horizontal direction, is restricted to heavier soils, e.g., on the Deccan trap formations and on light soils in Madras. It is particularly helpful for a quick preparation of the land, but such shallow ploughing has its obvious defects specially in the heavy soil, as it does not quickly take up a considerable fall, and may ultimately lead to erosion. In the majority of tillage experiments in India inversion and depth of ploughing have gone hand in hand and it is not possible to find out the effect of each factor separately. Some results of comparative studies on the efficiencies of the three forms of tillage are indicated below.

28. For *kharif* crops, inversion or greater depth does not increase the yield over that secured by using a paring implement or a light country plough. Moreover, the inversion plough will be uneconomical due to the heavy cost of operation. On sloping lands, deep ploughing at frequent intervals is desirable, as this kind of ploughing was found to reduce erosion when compared with the other two types of ploughing. It is indicated that inversion to a depth of 5 to 6 inches under conditions where the crop is dependent on monsoon precipitation is a sound practice. Inversion appears to be more effective under irrigated than under the rainfed conditions. Lands of greater fertility and those manured give, as a general rule, a greater return when put to inversion ploughs. In certain areas, inversion has little advantage over a good paring, except in the matter of eradication of perennial weeds. With light soil deep ploughing is not admissible, and with a heavy irrigated soil, where *kharif* staples are concerned, no great benefit is obtained by deep ploughing and inversion. Periodic inversion is helpful in such cases. It appears, however, that there is scope for the further study of different methods of tillage and mechanized implements in relation to reduction of costs of production and increased productivity.[12]

Tillage implements

29. Timely conduct of tillage and other cultural operations is an important factor in determining the yield. Mechanized methods offer a solution of the difficulties arising out of dearth of labour when it is most needed and of existing time-consuming methods. In large holdings mechanization and improved implements should be helpful if skilled labour and necessary capital are available. The majority of farm operations in India are, however, carried out to-day by bullock and manual power.

30. It is desirable, however, to initiate newer and better machinery to replace bullock and manpower, keeping the small holder predominantly in view. The benefits of such innovations can only be brought home to the cultivators by demonstrations of their practical usefulness in rural areas. Certain operations call for more labourers than are readily available at the opportune time. Climatic conditions also reduce the time factor. In such emergencies improved implements will be a great help and it is possible by way of mutual agreement for a group of farmers to take advantage of a single set of machinery. Harvesting and threshing may also be considered along similar lines.[13]

Social and economic factors

31. Reference has already been made to the poverty of the producer. Often a great difference is noticed between the yields obtained by the peasants in the same locality on similar soils. The fertility an efficient peasant has built up sometimes disappears on his death or cessation of his ownership. Evidence has already been given in paragraph 22 that it takes considerable time to build up soil fertility by judicious application of manures and fertilizers. Partition of holdings through the laws of inheritance also often leads to the same fate of the soil. In many parts of our country land is extensively cultivated on a crop-sharing basis, the owner of the land receiving generally half of the yield and sometimes even more. Often

peasants have not sufficient land so that they can make agriculture their sole occupation for obtaining a living. Disease is widespread in the villages and this hinders the execution of timely agircultural operations. Besides there is no certainty that they will continue to get on lease the same lands from year to year. All these factors make it difficult to continue efforts to build up or maintain soil fertility at a high level. It is very desirable that a survey be made to obtain information as to how these factors are limiting the productivity of the soil even under existing conditions, for some of them appear to be capable of redress. Effective measures taken with this object in view may yield a comparatively quick result.

32. In an area known to the writer where canal irrigation is available, two of the best farmers with whom finance is not so much of a limiting factor have been obtaining yields of 3,300 lb of late paddy per acre (unhusked) in their best soils. In the major portion of the area the better cultivators get an average of 2,400 lb of paddy, while land leased to peasants who cannot make agriculture their only occupation as they have not sufficient lands, or cannot for one reason or another provide the resources considered adequate under rural conditions the average yield is 1,400 lb. In contiguous areas under rainfed conditions, the over-all average comes up to 1,000 lb. It has also been observed when these low-yielding soils are taken up by owner peasants the yield goes up regularly, but it generally takes five to eight years to build up the soil fertility.

Possibilities of obtaining more than one crop

33. In the same area on the medium lying lands, where drainage is more rapid after the monsoon and which can be irrigated, three crops can be taken. The rotations followed not regularly but in a general empirical way are as follows :—

first year	*second year*	*third year*	*fourth year*
	green manure (sometimes)		
early paddy	early paddy	early paddy	sugarcane
lentil (*Lens esculenta*)	potatoes	potatoes	
sesamum	onions	sugarcane	

34. There is no regularity of the successions as stated above. Climatic and soil conditions are quite favourable for more than one crop in many areas. It has already been mentioned that facilities for irrigation and drainage should make it possible to increase the area under more than one crop. The yields generally obtained in the above-mentioned area are as follows :—

aus paddy . . .	800 lb
sesamum . . .	150 lb
lentil	200 lb
sugarcane . . .	90,000 lb
potatoes	9,000 lb
onions	8,000 lb

Under better conditions higher yields are obtained which for potatoes and onions may be double or even more.

Suitability of the soil

35. Owing to pressure of population and the emergency needs from the point of view of subsistence farming, the peasants are sometimes forced to grow crops on land which is not the best for those crops. For the purposes of planned production of food and the best utilization of soil resources, the suitability of the soil for particular crops should be ascertained with care. Reconnaissance soil surveys and detailed surveys in selected regions, especially in intensively cropped areas, should form the basis of land use. In regions of settled agriculture useful information is already available as a result of experience.

36. More attention should be paid to mixed farming and animal husbandry.[12] Pure grain farming confronts the peasant with practical economic difficulties. If the emphasis is shifted to livestock products, the peasant can hope to increase his prosperity in a surer way. By taking recourse to mixed farming, the time of the peasants will be more evenly spread throughout the year and devoted to useful purposes. Another advantage is the opportunity to replace productive for unproductive animals. A cow may be substituted for a bullock, and although thereby the milk yield may be reduced, the loss will be small compared with the cost of keeping the bullock fed and in good condition of health for the whole of the year.

37. The question of damage done to crops by various pests and diseases and that of spoilage of stored grains, measures of control, plant introduction and breeding in relation to the production of high-yielding and disease-resistant varieties, etc., will be dealt with by my colleague Mian Afzal Hossain. A considerable amount of success has already been achieved in evolving newer and better varieties of sugarcane, wheat, rice, cotton and some other crops. But here also much still remains to be done. Appropriate and efficient methods of combating insect pests and diseases require to be made available for use by peasants.

Interchange of information

38. The information about the various agricultural operations, level of productivity and means to raise it, measures taken to initiate research on particular aspects of agriculture, agricultural research organizations, and many other topics will obviously be found to be of common interest to various countries, especially if they happen to be somewhat similarly placed as regards soil, climate, crops, etc. Each country will benefit from interchange of information, personnel and conferences.

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REFERENCES

[1] *Agricultural Statistics of India*, Vols. 1–11.

[2] *Census of India*, 1941.

[3] *Imp. Coun. agric. Res. Misc. Bull.* No. 57, 1943.

[4] *Report on the Marketing of Potatoes in India and Burma*, 1941.

[5] *Estimates of Area and Yield of Principal Crops in India*, 1940–41, and the *Indian Trade Journal*, 1941–1945.

[6] *Agricultural Statistics of India*, Vols. 1–11, and *Census of India*, 1941.

[7] *Imperial Council of Agricultural Research—Memorandum on the Development of Agriculture and Animal Husbandry in India*, 1944, p. 18.

[8] *Agricultural Statistics of the United States Department of Agriculture, Washington.*

[9] *Journal of the Central Board of Irrigation, India*, Vol. 2, No. 4, p. 162, 1945.

[10] Figures supplied by the Assistant Agricultural Production Adviser (Manures), Government of India.

[11] *Mysore Journal of Agriculture*, Vol. 23, No. 2, p. 75.

[12] From a note supplied by Mr C. H. Parr, Head of the Division of Agriculture, Imperial Agricultural Research Institute, New Delhi.

[13] From a note supplied by Mr D. T. Brown, Head of the Division of Agricultural Engineering, Imperial Agricultural Research Institute, New Delhi.

LAND UTILIZATION AND SOIL CONSERVATION IN THE UNION OF SOUTH AFRICA

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PHYSICAL AND HUMAN BACKGROUND

The Union of South Africa comprises a total area of about 472,550 square miles, or 143,000,000 morgen.* The greater part of the country, some 406,000 square miles or 86 per cent of the total area, has a summer rainfall and is therefore subject to a regular six months' winter drought; the remaining 66,000 square miles include a small area of 16,000 square miles in the south with rainfall all the year round, and 50,000 square miles in the south western Cape with a winter rainfall and a regular six months' summer drought. The rainfall declines from east to west as the country flattens and over a very large part of the inland plateau of summer rainfall, conditions varying from extreme aridity to semi-aridity prevail. In fact only one third of the total area receives a rainfall of 25 inches or over per annum, and 25 inches is roughly the lower limit for successful crop production in summer-rainfall areas.

Apart from the low rainfall over most of the summer-rainfall area and its strictly seasonal nature, the precipitation is characterized by certain irregular features which lessen its effectiveness. Chief among these are the extreme variability of the total rainfall from year to year, and its variable distribution within any particular season. As a result, both seasonal and intermittent droughts are of common occurrence. A disproportionate percentage of the total precipitation frequently occurs in torrential thunderstorms, leading to a heavy loss in run-off. High evaporation is another factor tending to reduce the efficiency of the rainfall.

Furthermore, the agricultural potentialities of the Union's soils are strictly limited. Such good soils as are found are patchy in occurrence. Large areas, although not too dry, are stony and incapable of cultivation. Then, too, denudation is a permanent threat to the Union's soil resources. The soil is easily pulverized in the dry winter months, so that dust storms are common and, with the torrential downpours in summer, erosion is further aggravated, particularly in uneven country.

Of the total land available for farming, barely 6 per cent is under cultivation and it is unlikely that more than 15 per cent. can ever be cultivated, the remainder being too arid, stony or mountainous to permit of cultivation. Land under irrigation is unlikely to exceed 1,000,000 morgen at any time, so that any addition to the country's arable production through irrigation must remain small. It follows that over the greater

* 1 morgen = 2·117 English acres.

part of the country the unit of farm land must remain relatively large and must be used for 'ranching' or extensive pastoral farming, except where the existence of irrigation facilities makes possible a more intensive type of farming.

The total population of the Union is a little over 10,000,000, including some 2,000,000 Europeans and 8,000,000 non-Europeans, the latter consisting chiefly of natives, with a fair number of coloureds and Asiatics. According to the 1936 census (the latest available), just under 700,000 Europeans and just under 5,900,000 non-Europeans were classified as *rural*, or 35 per cent and 74 per cent, respectively, of the total in each group. The figure for rural non-Europeans includes natives in 'reserves,' which are areas set aside exclusively for native occupation; the rest are scattered throughout the country, some on their own farms, but the great majority on European farms as farm labourers.

The total land farmed by Europeans amounts to some 100,000,000 morgen, divided up into something approaching 120,000 farms. The total area of the existing native reserves is about 10,000,000 morgen; and according to present plans, this will be increased to some 16,000,000 morgen in due course. The remaining land, a little under 30,000,000 morgen, includes urban areas, roads and railways, national parks and unallocated land held by the Crown.

This is in brief the physical and human background against which the development of farming in the Union must be visualized. A more complete review of these aspects will be found in the third interim report of the Industrial and Agricultural Requirements Commission, entitled 'Fundamentals of Economic Policy in the Union' (1941). It is evident that as a result of natural limitations, the Union cannot be regarded as richly endowed from an agricultural point of view. But this does not detract from the fact that farming is the direct source of livelihood of 35 per cent of the European population and 74 per cent of the non-European population, or practically two-thirds of the total population. Nor does it detract from the vital role that farming has to play in feeding the nation and supplying raw materials for the manufacturing industries.

AN ERA OF LAND EXPLOITATION

South Africa is a young country agriculturally and the record of its farming development to the present date is, like that of most other young countries, essentially a story of land exploitation.

Commercialized agriculture in the Union has developed from very small beginnings in the course of the past sixty years or so. Previously a small scattered white population lived on large expanses of the country with their flocks and herds and farming then was little more than subsistence farming, producing the simple needs of the farmer and his family. Their requirements in respect of clothing and other manufactured articles were small, and the production of the small surpluses for obtaining these articles was not a difficult matter.

With the development of mining and all the associated activities of urban life, when towns became large centres, bigger demands were made of the farmers. Farms became cut up into smaller units and interest was

centred upon the commercial aspects of farming, rather than on the achievement of a stable way of life on the land. Much land came into production that had never been farmed before.

Virgin land of course possesses stores of fertility built up by natural processes through the ages. It was an easy matter, after the initial breaking of the farms, to convert this soil fertility into cashable material. This was done on a considerable scale, on the assumption that the soils and veld were stable and naturally maintained their productivity. There was plenty of land available and the utmost freedom was allowed. Ownership of land carried with it the right of the owner to do exactly what he liked with it—to drain it, to plant trees, to plough steep slopes, to overgraze catchment vleis, to cut the natural bush, and so forth.

The effects of this freedom of action, when influenced by world commerce and competition, are being felt to-day. All attention in the early days was devoted to economic production. The question of permanence in agriculture received little attention. The Union is faced to-day with huge problems arising from this emphasis on production without due consideration of the issues of permanent agriculture.

Widespread veld deterioration and denudation, accompanied often by extensive encroachment of inferior or noxious vegetation, are to be observed to-day all over the country. Declining crop-yields and abandoned lands tell of soil impoverishment on a wide scale. These are the forerunners of soil erosion (by water and by wind), which is already rife in the Union and advancing at such a rate that it is rightly regarded as the most serious of all menaces to the future welfare of the nation. Apart from wastage of soil on an appalling scale, the same factors responsible for erosion are profoundly changing the character of the natural water supplies of the country, leading to ever-increasing desiccation and greater severity of drought effects and, paradoxically, to increased frequency of disastrous floods. The inevitable associates of the foregoing are impaired nutrition of both crops and animals, increased susceptibility to disease and parasitism, and a progressive intensification of the general disabilities of farming.

In the more arid regions of the Union, meat and wool production have caused marked retrogression, erosion and the wholesale degradation of the flora, through total removal of the valuable natural herbage or its replacement by inferior plants. The resultant reduced carrying capacity and increased drought effects and susceptibility to disease are reflected in the heavy annual mortality among farm livestock. Particularly in the Karroo and in the areas just west of the Drakensberg range, erosion has reached the most serious stage and most of the larger irrigation dams are in danger of being rendered useless by siltation. In the mixed farming areas the position is somewhat better, although far from satisfactory. In the better watered parts we had a golden opportunity to follow the rules of permanent agriculture worked out over the centuries in Europe. Our activities have, however, been guided far more by market demands than by soil demands, and over wide areas land has been depleted by straight cropping without rotations, by grain removal without the replacement of manure or the periodical inclusion of grass crops for building up soil structure. Even in the maize-producing areas, where, owing to suitable soils and climate, crops can be produced with regularity, we are faced with a position where

active measures are now called for to maintain soil fertility, to conserve the soil and to retain the rainfall.

The situation revealed is indicative of the existing general instability of farming in the Union. It is a direct outcome of exploitative methods of land utilization in farming practice, farming which lays all the emphasis on production with little or no thought of conservation, which is a constant fight against instead of a smooth co-operation with Nature, and which culminates in the destruction of the inherent stability of the soil. The term ' stability ' as used here implies the natural combination of physical, chemical and biological conditions which determine the character of the virgin soil, notably its productiveness and resistance to erosion. Failure to maintain the stability of the soil lies at the root of the whole matter. The two main causal factors in farming practice are, firstly, abuse of the natural veld by injudicious burning, overstocking and improper management, whereby the vegetal cover declines in both vigour and quality and the soil becomes increasingly denuded and exposed to erosion by wind and water, and secondly, the extensive and often indiscriminate ploughing-up of veld for the production of grain and other cash crops, without due regard to the maintenance of tilth and fertility, particularly in marginal areas where crop production is at best a gamble. In both cases the final outcome is the same, the stability of the soil is gradually but surely undermined and active erosion sets in.

In passing, attention may be drawn to the stupendous loss of soil fertility that results from modern methods of sewage and garbage disposal in the towns. The vast quantities of farm products that are transported to and consumed in the towns represent an enormous drain on the fertility of the producing areas. A large proportion of this fertility is recoverable in the sewage and other wastes, which are to-day in most cases so effectively destroyed. The return of these wastes, suitably processed, to the producing areas would go a long way towards checking the present rate of impoverishment of the latter.

Attention must also be drawn to the role played by natives in causing erosion, both on European-owned farms and in their own reserves. The system of ' labour farms '—European owned, but farmed by natives, without restriction—is creating desolation in parts of the country. Roads and railways too call for mention as potent contributory causes of erosion in the farm lands traversed by them.

THE MENACE OF SOIL EROSION

Man-induced erosion is of course no new phenomenon, but as far as modern countries are concerned, the most serious damage has occurred during relatively recent years, when a period of enormously accelerated erosion set in. As G. V. Jacks (' *Rape of the Earth* ') puts it : ' the unprecedented economic expansion during the later nineteenth century has been followed by a world-wide deterioration of the land, and probably more soil has been lost from the earth since 1914 than in all previous human history.'

Reliable figures as regards the extent of soil loss in the Union due to erosion are lacking, but a rough computation by the Drought Investigation

Commission (1923) placed the silt load carried by some of our principal rivers at 187,000,000 tons during the single season 1919/20. Bearing in mind that the silt transported by rivers does not represent the total extent of soil loss due to erosion, that the Commission ignored several important rivers, and that the situation as regards erosion over the country as a whole is undoubtedly far more serious to-day than it was in the days of the Commission, it seems safe to conclude that the present annual rate of soil loss is considerably greater than the tentative figure given for the year 1919/20.

As a more or less intelligent guess, based on local observation supported by the analogy of American figures, the writer suggests that the current rate of soil loss in the Union can hardly be less than 300,000,000 tons per annum. But whatever the figure may be, it is obvious that erosion is costing the country a prodigious sum annually, represented not only by the capital value of the soil fertility lost, but also by the loss of potential farmer-income and the cost of flood, siltation and other damage.

In any case, erosion is now rife in every corner of the Union and it is the writer's conviction that not one farm in twenty is better than or even as good as it was say twenty years ago, and that over the country as a whole erosion has already destroyed upwards to one-fourth of the original fertility reserves of the Union's soil. The position is alarming enough in European farming areas, but even more so in native reserves, where the problem is aggravated by severe human congestion and overstocking.

In the circumstances, it is hardly surprising that Jacks and Whyte ('*Rape of the Earth*') should state that a national catastrophe due to soil erosion is perhaps more imminent in the Union of South Africa than in any other country visited by them, that the tragedy of South Africa has been the appalling rapidity with which its fertility reserves have been depleted and its thin soil covering washed away, and that in no other country have the disastrous consequences of erosion followed so quickly after its commencement.

Actual soil loss due to wind or water erosion is the most obvious manifestation of land abuse. No less sinister in its menace to the future, however, is the ever increasing desiccation that marches hand in hand with erosion. The total rainfall over the country as a whole has not changed, although in many areas local changes in both quantity and distribution are claimed to have occurred, notably where extensive areas of naturally well wooded country have been deforested for timber or firewood purposes.

More obvious, however, is the fact that the advance of erosion greatly accelerates the drainage of the countryside and leads to a lowering of the water-table. The result is that countless fountains and streams, that once flowed strongly all the year round, have now disappeared or at best flow only sporadically. Our rivers, where in all probability clear water once flowed perennially, subject only to seasonal rise and fall, are now characterized by violent fluctuations in volume over short periods of time. What is now little more than a dry water-course during the dry season of the year, may be converted by heavy rains into a raging flood of silt-laden water, which again subsides to almost nothing in a matter of days.

Whereas the rain was formerly retained where it fell and gradually seeped through the soil to feed numerous fountains and permanent water-

ways, in an eroding area the bulk of it rushes over the surface and along erosion channels to empty itself (with its load of silt) as quickly as possible into the nearest river. The finest silt finds its way to the sea, but the heavier material is deposited along the lower reaches of our main rivers, gradually raising the river-beds and increasing the frequency and seriousness of floods in those parts. Enormous masses of silt are also being deposited in most of the huge irrigation reservoirs built by the State at great cost, and threaten to render futile the purpose for which they were constructed.

A particularly potent factor contributing to the general desiccation of the country is the wilful destruction of natural 'sponges,' that were designed by Nature to play a vital role in the maintenance and regulation of permanent water supplies. The repeated burning and over-grazing of mountain catchment areas, where our permanent waters in the main have their origin, is a case in point. Such denuded mountain catchments are an important contributory cause of flood damage along the lower reaches of our larger rivers. Another is the deliberate practice of draining natural 'vleis,' as a preliminary to ploughing up the areas for the production of crops. To-day some of the worst examples of desiccation and erosion are to be found on the sites of former vleis.

Enough has been said to indicate that man's influence has caused a profound change in the character of the water resources of the Union. Droughts we have always had and always shall have, but it is hardly to be wondered at that, what would formerly have been regarded as a relatively insignificant drought, now tends to assume the proportions of a major disaster, accompanied often by actual shortage of drinking water.

THE NEW ERA OF SOIL CONSERVATION

For present purposes it is not proposed to elaborate on the technicalities of the Union's soil erosion problem as such, a matter which is dealt with in some detail in a report drawn up by a committee of senior officials of the Department of Agriculture and published under the title '*Reconstruction of Agriculture*,' 1943. Suffice it to say that the causes and consequences of erosion, as well as its remedies, are now reasonably well understood, and basically the problem is much the same in all countries, varying only in degree.

Of greater immediate significance is the realization which has swept over the whole world that soil conservation is the only real and permanent basis of human conservation and national security—or, to carry the matter a stage further, that a stabilized farming industry, which implies conservation of soil resources, is a *sine qua non* of a stable national economy.

With particular reference to South Africa, it is widely conceded to-day—by farmers as well as townsmen—that ownership of land cannot be allowed to carry with it the right of the owner to abuse and destroy that land; that the occupation of land, by owner or tenant, must be on a basis beneficial to the nation as well as to the individual, and that it is incumbent on the State not only to give guidance in regard to wise land utilization, but also to exercise such controls as may be necessary to ensure this and to safeguard the agricultural resources of the nation for posterity.

It is of course true that a great deal of land abuse, with consequent soil

erosion, is due to *economic pressure*, which often forces the farmer to overwork and exploit his land in order to meet his commitments and at the same time maintain a decent standard of living. The chief factors of this economic pressure are, firstly, inflated land values, with resultant over-capitalization, often accompanied by excessive mortgage indebtedness, secondly, the sub-economic size of many farm holdings, and thirdly, the inequitable prices often received for farm products in relation to the costs of production. Any policy aiming at the stabilization of farming and the elimination of land exploitation must obviously take these factors into account. But it is equally true that, in the absence of stability in the methods of using the land, there is no secure foundation for the establishment of a sound farming economy—in such circumstances, indeed, all purely economic measures (notably price assistance) are usually only palliative in effect and in the long run often serve to aggravate the position which they were intended to remedy. It is the interplay of such maladjusted economic and land utilization factors that lies at the root of the economic disabilities of the farming industry and the wide prevalence of exploitive farming to-day.

The dominant problem of agriculture, therefore, is to *stabilize farming practice on the land itself* in accordance with the soil—veld—climatic environment and with conservation as the keynote of farming policy. It is only in this way that an end can be put to the present era of land exploitation, and that the factors constituting economic pressure on the land can be adequately dealt with and a clear perspective obtained on such fundamental issues as land values, economic sizes of farm units, equitable prices for farm products, the production potential of the country and the ability of farming to cater adequately for the nutritional requirements of the present or future population.

The discussion that follows relates exclusively to the land utilization aspects of the problem, the necessary economic adjustments being taken for granted. And since it is, in the first instance, the duty of the State (in co-operation with the farming community) to ensure that the land is used correctly, it is proposed to devote the remainder of this paper to a brief consideration of the role that has been, is being and must in the future be played by the State in this connexion.

STATE ACTION TO DATE

The first comprehensive review of the soil erosion problem in South Africa was given in the classical report of the Drought Investigation Commission, which appeared in 1923, nearly twenty-three years ago. The Commission depicted the 'gloomy and ghastly future' which lay before the country if the processes of soil erosion and desiccation were allowed to continue, and issued the grave warning that the logical outcome could only be 'the great South African Desert, uninhabitable by man.' One recommendation pertinent to our present discussion reads to the effect that, first and foremost, the State was obliged to take action in connexion with soil erosion, for if erosion were allowed to continue unchecked, it would lead to national ruin. It was pointed out that the

individual also had his responsibilities and that without his co-operation the damage could not be repaired, for prevention and sustained vigilance were essential and no State organization could ever supply the close watch which was necessary. The Commission did not consider that the time was yet ripe for direct legislation; in their view education of public opinion was first required and thereafter direct legislation would be necessary.

The report, which even to-day must be regarded as one of the best 'blue books' ever issued, marks the first official attempt in this country at a systematic and co-ordinated analysis of the basic disabilities of farming in the Union. It attracted wide attention and did a great amount of good, not only in offering useful practical suggestions to farmers regarding erosion control and the improvement of their farming methods, but also in focussing public attention on the vast inter-related problems of soil erosion and drought.

The next event of significance was the holding of a representative Soil Erosion Conference at Pretoria in 1929, 'to have a free discussion and interchange of views among the various State Departments and other bodies closely concerned with the problem of soil erosion, with a view to evolving suitable lines of action for dealing effectively with the problem.'

This Conference served a useful purpose in clarifying some of the main issues as far as the organization of erosion control activities was concerned. The need for close co-ordination of activities among the various State Departments and other public and private bodies concerned was stressed, and it was clearly laid down that the prime responsibility in the whole matter lay with the Department of Agriculture. A proposal to establish a permanent Soil Erosion Advisory Council emanated from this Conference and the need for a separate organization (under agriculture) to deal with soil erosion was stressed. Incidentally, the resolutions taken embody the first official suggestion as regards the granting of assistance to farmers for the combat of soil erosion.

In the following year the Soil Erosion Advisory Council was established, representative of all the Departments and other bodies who attended the original conference, and under chairmanship of the Secretary for Agriculture. This Council met on several occasions between 1930 and 1933, after which it ceased to function. To cut a long story short, the recommendations made by the Council resulted in the Government approving of a number of *Soil Erosion Schemes* which were launched in 1933. These schemes provide for the subsidization of anti-erosion works, including dams and reservoirs for stock-watering purposes, and three years later the so-called *Silo and Stockshed Scheme* was introduced, with a view to encouraging greater attention to fodder conservation. Due to the war emergency, all these schemes were suspended in June, 1940, but they were again partially reinstated as from April, 1942. It may be of interest to note that the total expenditure by the Government under these schemes to date amounts to close on £2,500,000, most of which represents direct benefits received by farmers.

At about the same time when the soil erosion schemes were launched, funds were provided for *research on soil and veld conservation* and some sixteen odd conservation stations (known as Pasture Research Stations)

have since been established in various parts of the country—this of course in addition to the wide range of agricultural and veterinary research carried out at various other experiment stations and research institutes controlled by the Department of Agriculture. The total expenditure under the head of pasture research alone, excluding staff, is in the neighbourhood of £300,000 to date, and during the same period a sum of about £100,000 has been made available to universities and agricultural colleges for research and field studies in connexion with soil, veld and water conservation.

Concomitant with the foregoing developments, a great deal of attention has been given to the closely related problems of *weed control*. The encroachment of useless or noxious vegetation on both arable and grazing land is a constant threat to farming in every part of the Union and has already rendered large tracts of country all but useless for farming purposes. With the passing of the Weeds Act (No 42 of 1937) the central Government assumed full responsibility for the administration of weed control, an onus which previously rested on the individual Provinces. A fairly elaborate Weed Inspection Service was then called into being and a total sum running to several hundred thousands of pounds has been spent by the Government to date on the control and eradication of noxious weeds.

Another part of the State conservation programme has been concerned with the *expropriation and permanent protection of important mountain catchments*, in terms of the earlier Forest Act and various Ordinances that have since been consolidated under the present Forest and Veld Conservation Act. Over 1,000,000 morgen of land have been acquired under this head, the primary object being the protection of water sources. In the absence of a special conservation organization, this land has been entrusted to the care of the Department of Forestry, which Department has also, for the same reason, been held responsible up to the present for *drift sand reclamation* along our coastal areas.

A logical outcome of all these activities was the creation, towards the end of 1939, of the Division of Soil and Veld Conservation, thus giving effect to the recommendation of the Soil Erosion Conference held ten years previously that a special organization under the Department of Agriculture should be established to deal with soil erosion. As a start towards the development of an effective soil conservation service, this Division was charged with the direction and co-ordination of all activities in the fields of pasture research, weed eradication and erosion control. Unfortunately for the plans then entertained, the new Division was born just at the outbreak of war in 1939. As a result of war conditions naturally it has been impossible to make the progress that might otherwise have been expected during the past six years.

Yet considerable progress has been made as regards both research and field activity. A particularly significant development was the passing of the Forest and Veld Conservation Act (No 13 of 1941), embodying the first attempt at comprehensive legislation to deal with soil erosion and related problems. Section 4 of the Act makes provision for the expropriation by the State of any area of land required for drift sand reclamation, or for erosion control, or for the conservation of water sources, while section 5 provides for the proclamation, in the discretion of the State, of any area of land as a conservation area, such proclamation implying an

undertaking by the Government to proceed with the reclamation and conservation of all land falling within the area.

When a conservation area has been duly defined and proclaimed, the State has full power to expropriate any land within the area and to reclaim such land at its own expense ; or, alternatively to compel the landowners concerned to adopt such reclamation and conservation measures and methods of land use generally as it may prescribe. In practice, of course, the ' compulsion ' aspect is kept in the background and every effort made to secure the goodwill and co-operation of the landowners.

The expropriation powers under section 4 have already been used extensively for the acquisition and protection of mountain catchments already referred to, and two conservation areas have been proclaimed in terms of section 5 of the Act. These are :—

(i) *The Vlekpoort Conservation Area*, proclaimed in 1941, embracing some 290 square miles (87,000 morgen) of severely eroded land in the valley of the Vlekpoort river, Maraisburg district, Cape, and

(ii) *The Drakensberg Conservation Area*, proclaimed in 1944, covering some 3000 square miles (roughly 1,000,000 morgen), bounded by the Mooi and Tugela rivers from their confluence to their sources in the Drakensberg mountains, with the Natal-Basutoland boundary as the western limit.

Work has been proceeding in both areas as actively as circumstances permit, under the direction of the Division of Soil and Veld Conservation, or of Soil Conservation and Extension, as it is now known. Certain farms have been expropriated and are being reclaimed at State expense, and the State also undertakes what are known as ' major ' works. For the rest, the landowners themselves are expected to carry out the works and farming plans prescribed for each farm. As an inducement to this end they are offered generous bonus facilities and substantial loans on easy terms. Experience has shown that the farmers are only too eager to co-operate, so much so that many requests have been addressed to the Government for the proclamation of further conservation areas in various parts of the country.

The need for *field surveys* on a Union-wide basis, in order to furnish the factual background for intelligent farm planning, has of course not been overlooked. A start was made many years ago with systematic soil, vegetation and so called agro-economic surveys of the Union, and these have contributed a mass of valuable information in regard to our basic farming potentialities. But the picture is far from complete as yet. All survey activities had unfortunately to be suspended shortly after the outbreak of war, but they will be resumed and prosecuted more actively than ever as soon as conditions permit.

THE POSITION TO-DAY

This brings us to the present day, where we are forced to realize that the situation as regards erosion and desiccation over the country as a whole has not improved, but deteriorated since the days of the Drought Investigation Commission. All the destructive practices that give rise to

erosion are still rife in farming to-day. The record of past achievements is no mean one, but notwithstanding all that has been done for the betterment of farming by way of research and experimentation, education, propaganda, advisory and regulatory services, improved marketing and distribution, reduced tariffs, anti-erosion schemes and various other forms of State assistance, there is little evidence of general improvement in the systems and methods of farming over the Union as a whole. Moreover, leaving out the war years when abnormally high prices prevailed, the total value of agricultural production has shown no marked upward trend during the preceding ten years or so, although there is no doubt that the Union's farming is capable of a much higher level of production.

Although substantial progress has been made in a number of directions, one can only conclude that the sum total of positive achievements is more than offset by the general retrogression which is still taking place due to unsound methods of land use, accompanied by a progressive undermining of the soil, veld and water resources upon which the whole farming structure rests. The fact is that, while many individual farmers have taken full advantage of the various facilities offered by the State and have succeeded in placing their farming on a sound and stable footing, the general progress in this direction has been far too slow, with the result that exploitive farming is still the rule rather than the exception.

As a case in point, it may be mentioned that barely 10 per cent of our farmers have taken advatage of the facilities offered under the various soil erosion schemes and the silo and stockshed scheme. The over-all position to-day, therefore, is that veld deterioration, fertility depletion, soil erosion and desiccation are still proceeding apace, and weed encroachment is forcing more and more land out of production.

The position is hardly more reassuring as regards the efficacy of our farming industry in fulfilling its primary function of *feeding the nation adequately*. The National Nutritional Council drew attention to the extent of human malnutrition in the Union in its report issued in 1944. Based on the nutritional requirements of a total population of some ten million persons, it appears that only in the case of cereals and sugar does production exceed requirements. In all other cases there is a more or less pronounced shortfall, notably in respect of protective foods of animal origin (meat, milk, butter, eggs, etc.). This disproportion in farming production is due largely to the bugbear of effective demand and the modern tendency of farming to specialize in production, one result of which has been over-concentration on the production of cash crops for sale as such. This policy is detrimental both to the soil and to the health of the people. From both points of view a greater degree of diversification in farming, individually and collectively, is called for, notably in those areas where the production of grain and other cash crops plays the dominant rôle.

Adequate nutrition and soil stability will have to be accorded first place in any planned national economy and there is little doubt that rational land utilization can lead the farming industry to a condition of stability in which it supplies the food that the country needs for both its present and future population. It is of course realized that the problem of malnutrition is largely an economic one, but unless the efficiency of agricultural production is increased and maintained, so that adequate food of good quality

becomes available for all who need it, there is little hope of the nutritional ideal envisaged by the Nutritional Council ever being attained.

Taking all circumstances into consideration, it has become obvious that vigorous State action on a scale far exceeding anything attempted to date is called for in order to secure the rational utilization and conservation of the nation's agricultural resources.

FUTURE POLICY AND PLAN OF ACTION

It is a happy augury for the future that the people of the Union, urban no less than rural, have become markedly 'conservation conscious' and are prepared to give their full support to a comprehensive national campaign of farming rehabilitation and soil conservation. The Government's view of the matter is reflected in a recent public statement by the Prime Minister, Field-marshal J. C. Smuts, that soil conservation must be regarded as priority number one of post-war reconstruction.

It is perhaps unnecessary to stress the fact that land utilization and soil conservation are inseparable concepts. Soil conservation of course includes specific reclamation measures, largely of a mechanical nature, which are called for in dealing with areas that have already suffered considerable abuse; but it goes much further than this, since the keynote of conservation is prevention. This again implies sound systems and methods of land use in farming, the aim of which is to increase the production from farming and to maintain it at the highest level that is compatible with proper conservation of soil, vegetation and water resources. Even when the problem is primarily one of reclamation, the mechanical measures adopted cannot be fully effective unless coupled with appropriate land utilization measures.

As regards the new era of soil conservation into which the Union is now entering—and has in some respects already entered—reference may be made to the following publications :—

(i) The Departmental report already referred to, entitled '*Reconstruction of Agriculture*,' 1943;
(ii) A report by the Social and Economic Planning Council on '*The Future of Farming in South Africa*,' 1944 and
(iii) A White Paper issued by the Union Government on '*Agricultural Policy*' 1946.

The first two documents represent independent attempts to diagnose the weaknesses and disabilities of farming in the Union and to lay down the basis of a long-term agricultural policy for the future. While differences appear in regard to some of the economic issues involved, the reports are virtually unaminous as regards the practical issues of land utilization and soil conservation.

The White Paper is based on the two foregoing documents; it is an official declaration of the Government's agricultural policy and implies that the Government will take all necessary steps to carry this policy into effect without delay. Particular stress is laid on the need for a realistic national programme of soil conservation on the land, in which connexion it is pointed out that additional legislation will be required and is now

under consideration, and also that no effort is being spared to build up the strong field conservation service which is a first essential for the success of the whole campaign.

It may be appropriate now to discuss briefly some of the main features of the plan of action which is now in course of development.

ACTION IN THE FIELD

The high points of the contemplated field programme are as follows :—

1. *Expropriation and/or permanent protection of highly vulnerable areas,* notably important mountain catchments, the protection of which is necessary for the conservation of water sources and the maintenance of stream-flow in rivers. It is to be noted that this may in due course involve the shifting of certain native reserves situated in such vulnerable areas. It was mentioned earlier that about 1,000,000 morgen of mountain land had already been acquired by the State, but there is very much more that should be placed under protection.

2. *The launching of suitable schemes of subsidization to induce landowners to adopt specified conservation practices,* with the proviso that such practices must fit in with an approved plan of conservation farming, to which the landowner must undertake to adhere. Typical of such practices are—crop rotation, with inclusion of suitable soil-building perennials ; contour farming and strip-cropping on sloping land ; the adoption of efficient systems of grazing management, this again calling for vast quantities of fencing material and adequate stock-watering facilities ; the making of compost and the conservation of fodder in the form of hay or silage.

This will be a cardinal feature of the new approach to farming, the objective being to ensure, firstly, that the systems of farming practised are adapted to the prevailing natural controls of soil, veld and climate ; and secondly, that the methods and practices of land use within the approved systems conform to what is generally known as 'conservation farming.'

This implies a detailed survey of the farm resources and the drawing up of an appropriate farming plan for every farm dealt with.

A small start has been made by the recent launching of a scheme for subsidizing the establishment of lucerne as a rotational crop for soil building purposes in the wheat growing areas of the south-west Cape, and more comprehensive schemes are now in course of preparation. The Maize Subsidy Scheme of Southern Rhodesia comes nearer to the sort of scheme here visualized. It provides for the payment of a cash subsidy of 2s. per bag on maize grown under specified conditions, according to which one third of the area intended for maize production must be put down annually to sunn hemp or other leguminous crop for green manure or compost purposes and the entire area cultivated on contour.

3. *Establishment by the State of equipped gangs and mechanized units,* which will carry out approved reclamation and conservation works for landowners at a definite tariff. The works referred to include terraces, dams and other structures designed for erosion control or water conservation, as well as the eradication of major weed pests such as prickly pear, jointed cactus, thornbush, etc. Mobile labour camps and equipment depots will

be established in different parts of the country as required to serve particular areas, and the order of priority of areas to be dealt with will naturally be determined by the State. There is no doubt that this scheme will be acclaimed by landowners generally, as many of them are at a serious disadvantage, due to labour shortage and lack of the necessary equipment, much of which is very costly.

The full development of the scheme will have to await the time when sufficient personnel has been recruited and trained for this work and when equipment is again freely available. Departmental labour gangs are already undertaking prickly pear eradication for landowners in the Eastern Cape, the latter being debited with 50 per cent of the labour costs, subject to a maximum charge of 10s. per morgen, and it is anticipated that similar schemes for dealing with jointed cactus and thornbush will be announced shortly.

4. *Extension of the scope of the existing soil erosion subsidy and loan schemes,* to include all the types of works referred to in the foregoing section. The undertaking of work by the State as just described does not imply that landowners are to be discouraged from doing such work themselves. On the contrary, there is so much to be done that landowners must receive every inducement to do as much as they can themselves, even to the extent of employing private contractors for the purpose, if necessary. For example, associated with the scheme under which prickly pear eradication is carried out by the State against certain charges to the landowners concerned, a parallel scheme has been launched under which generous bonus and loan facilities are available to landowners who elect to do the work themselves.

It is anticipated that a similar procedure will be adopted in regard to all types of reclamation and conservation works.

5. *Proclamation of further Conservation Areas,* in terms of the existing Forest and Veld Conservation Act, as dictated by need and circumstances, especially where other methods of approach fail to achieve the desired results.

6. *Establishment of demonstration farms,* at strategic points all over the country. A demonstration farm continues to be farmed by the owner himself, but the farming system and methods of land use are laid down by local conservation officials—the farmer undertakes to adhere strictly to the prescribed farming plan, in consideration of which the State agrees to furnish essential fencing material or other requirements within reason.

In this way the correct farming systems for particular areas and the necessary conservation practices can be demonstrated and brought home to farmers in a particularly effective manner, on the principle that 'seeing is believing.' This method of approach has proved of very great value in the United States of America.

Demonstration farms have already been established in a number of areas and it is hoped to get many more going in the near future.

7. *Development of regional film services* for intensive propaganda among farmers and visual education in regard to sound land use and soil conservation. The film will be used here as a short cut to the same objective aimed at in the establishment of demonstration farms.

8. *Further development of the 'agricultural club' and 'land service' movements*, with a view to organizing the youth of the country to take an active interest in the land and its conservation. Through these movements many thousands of young people become imbued with the ideal of soil conservation as part of their normal philosophy and outlook on life.

Note—The foregoing items relate purely to the field programme, which is the primary function of the field conservation service. Needless to say this field programme will be supported and supplemented by a greatly extended programme of *research, surveys and education*, which form an equally essential part of the soil conservation campaign as a whole. The present paper, however, is concerned almost exclusively with the field approach, because it is in this respect that more drastic and realistic action is most urgently called for.

ENABLING LEGISLATION

While the Forest and Veld Conservation Act referred to earlier enables the Government in its own discretion to expropriate land or to proclaim conservation areas, and to impose such conditions as it wishes within such areas, it has several weaknesses, chief among which are that it makes no provision :—

(i) For co-ordination of the policy and activities of the various State Departments and other public and semi-public bodies which are directly concerned with particular aspects of the general problem of land utilization and soil conservation. Among State Departments alone, at least five are directly concerned, viz. Agriculture, Forestry, Lands, Irrigation and Native Affairs, but for all practical purposes each determines and carries out its own policy without reference to the others. It has long been felt that provision should be made for the creation of a national Soil Conservation Board, representative of the various State Departments concerned as well as of farming and certain other interests. It would be the function of this Board not only to ensure proper co-ordination of policy, but also to advise the Government in regard to the need for or application of soil conservation schemes, land-use regulations or any other matter pertaining to the general problem of soil, veld and water conservation. Under the Constitution of the Union, such a Board would have to answer to the Government through one particular Ministerial Head, and it seems clear that this should be the Ministry of Agriculture.

(ii) For the imposition of sanctions against definitely abusive or erosion-promoting practices of land use, or for the promulgation of regulations generally to govern the use or abuse of land. Under present conditions it is only within proclaimed conservation areas that such sanctions or regulations can be applied.

(iii) For voluntary action on the part of farmers to secure the proclamation of conservation areas and then to assume a large share of responsibility for carrying out approved programmes of soil conservation in such proclaimed areas. This is of course a cardinal feature of the practical approach to soil conservation in the United States of America and it is felt that this democratic method could

be used to great advantage in the Union. One visualizes here that in each 'voluntary' conservation area established, a responsible local committee should be appointed, composed primarily of farmers, but including one or two conservation officials. This committee would then control and direct the whole programme of action in the particular area.

With a view to rectifying these and certain other weaknesses and gaps in the existing legislation, the Union Parliament will shortly consider a new Soil Conservation Bill, which has been drafted as additional to the existing legislation. Since the Bill is *sub judice* at the time of writing, all that may be said at this stage is that it provides all the necessary legislative enablement for the effective carrying out of a realistic national programme of soil conservation, as has been outlined.

THE FIELD CONSERVATION ORGANIZATION

So much for policy, plans and legislation. Although it is intended to mobilize the farming community and to throw a large measure of responsibility on the farmers themselves, it is clear that the success of the whole undertaking depends in the first instance on the efficacy of the official conservation organization created to guide and direct the field campaign.

This responsibility devolves primarily upon what is known to-day as the Division of Soil Conservation and Extension of the Department of Agriculture. This Division replaces the former Division of Soil and Veld Conservation and is now, in effect, purely a field conservation service. Under the Department of Agriculture it is responsible for all reclamation and conservation activity in the field and also for all advisory and regulatory services to farmers that bear directly on systems and methods of land use in farming. The relevant research, survey and educational activities are controlled by other Divisions of the Department of Agriculture, which naturally function in close co-operation with the Division of Soil Conservation and Extension.

Soil conservation activity in the field has been decentralized on a regional basis, for which purpose the Union has been divided into five main regions (later probably to be increased to seven), each of which is controlled by a 'regional director' of soil conservation, supported by a balanced team of senior conservation officials. This group of officials constitutes the organizing and planning committee for the region. It is given as much local authority as possible and carries out all the functions of the Division of Soil Conservation and Extension in the particular region. A prime requisite, of course, is that each region must be staffed with adequate field personnel of conservation technicians—men who are in daily touch with the farmers and who do the actual work, or see that it is done.

The organization as outlined is unfortunately only in the formative stage at the time of writing. Shortage of qualified and experienced personnel is the most critical issue at the moment. All possible steps are being taken to recruit and train men for this work; but this takes time and it is inevitable that several years will have to elapse before the peak development of soil conservation activity in the Union is reached.

COST OF SOIL CONSERVATION

It is evident that the programme of action that has been outlined will involve the State in very considerable expenditure over the next twenty or twenty-five years, during which period the writer considers it imperative that the bulk of the work should be completed. At a rough estimate it is suggested that the total expenditure called for over this period may be in the vicinity of £100,000,000.

When arguing about the high cost of soil conservation, one must bear in mind the high cost of soil erosion to the country, as represented by the steady decline in soil fertility, reserves, the loss of potential farm income and the cost of direct and indirect damage caused by erosion. Added to this, American experience has proved, beyond doubt, that expenditure on soil conservation is not only an investment in national security, but that it pays very handsome dividends in the way of substantial over-all increases in the production from farming. Over vast areas to which conservation methods have been applied, production is reported to have jumped almost at once to an average of about 25 per cent higher than before, and to be still on the up-grade.

There is every reason to expect that local experience will be similar, for the total production from farming in the Union can undoubtedly be raised to a considerably higher level than it has ever attained in the past. The average gross value of our agricultural production during the three years prior to the war, 1936–1939, has been assessed at just over £60,000,000 per annum, and the net value at just over £44,000,000 per annum. It is certainly not too optimistic to believe that the volume of production represented by these figures could be increased by at least 50 per cent or even more, as a result of rational land use. This is indeed the ultimate aim of the national campaign of soil conservation which is now being developed. Thus, from all points of view, there can be no doubt as to the justification, and indeed the imperative necessity, of liberal expenditure by the State on soil conservation, even if such expenditure should run to millions annually.

To borrow a quotation from Dr Bennett : 'the programme of action will cost a great deal, but everybody will like it and it will pay magnificent dividends to the nation.'

References

1941. *Third interim report of the Industrial and Agricultural Requirements Commission : Fundamentals of Economic Policy in the Union.*

1923. *Final report of the Drought Investigation Commission.*

G. V. Jacks and R. O. Whyte. *The Rape of the Earth.*

1943. *Report of the Reconstruction Committee of the Department of Agriculture and Forestry : Reconstruction of Agriculture.*

1944. *First report of the National Nutritional Council.*

1944. *Fourth report of the Social and Economic Planning Council : The Future of Farming in South Africa.*

1946. *Union Government : White Paper on Agricultural Policy.*

H. H. Bennett. 1945. *Soil Erosion and Land Use in the Union of South Africa.*

MORNING SUBJECT (k)

DISCUSSION OF THE NEED FOR A CO-ORDINATED SURVEY OF THE MINERAL RESOURCES OF THE EMPIRE AND FOR OPERATIONS ON A MUCH LARGER SCALE THAN HITHERTO

STEERING GROUP

Chairman—Sir Thomas Holland, F.R.S.

Recorder—Professor W. R. Jones

Mr L. J. D. Fernando
Professor E. S. Hills
Dr M. S. Krishnan
Dr E. Marsden, F.R.S.
Dr E. S. Moore
Dr L. T. Nel

REPORT

The Conference heard with great interest descriptions of the various organizations in the Dominions and India dealing with this subject.

The Conference was unanimous in calling attention to the insufficiency, both in scale and in quality, of official activity inexploring the mineral resources of the Commonwealth. Except in one or two of the Dominions, geologists had been employed in numbers far too small to permit of appreciable regard to the high degree to which the geological group of subjects had become specialized.

The institution of a general geological map of each territorial unit was essential for profitable prospecting. The work of the field stratigrapher, however, could not be carried on without the help of palaeontologists, petrologists and mineralogists. Each line on a geological map requires the judgment of trained scientific officers, and in this respect geological mapping differed from ordinary topographical surveying in which much detail of a purely mechanical order could be recorded in the field. Similarly, the use of a general geological map as a guide to prospecting followed its interpretation by mining and mineral specialists who might be looking out for ' prospects ' of coal, of oil, of metalliferous ores or other minerals of economic value.

The scattered distribution of the Colonies and the varied natural features of the territorial units of the Commonwealth necessitated encouragement of activities which would reduce the tendency to export minerals in the raw state. For economic reasons, local processing to a much greater extent than hitherto would benefit each administrative unit. It would add also to its safety in times of emergency or temporary isolation.

It should be practicable for geographically and politically related colonies to federate the purely advisory functions of a geological survey, in order to obtain the benefits of reliable reference libraries and collections and to maintain a recognized medium for publishing results. The extent, however, to which a geological survey should be limited to advisory functions, or should become active also in prospecting operations, was a question upon which the opinions of delegates differed. Opinions varied according to differences in practice already established in the Dominions.

Delegates expressed some concern about the delay which must necessarily occur in effecting important reforms. On account of the uncertainty of obtaining suitable employment in geological survey work only small

numbers of university students had taken up the subject. In consequence it would be difficult to obtain immediately a sufficient number of qualified recruits to extend official operations on a scale which was regarded as urgently desirable.

The methods of the old-time prospector had been extended in depth and largely superseded by geophysical and geochemical methods. These, however, required close association with stratigraphers for their interpretation and practical application in prospecting. They had nevertheless, been especially successful in the search for buried rock structures suitable for the retention of oil stocks.

The work of the Imperial Institute, though done hitherto on a limited scale, was appreciated by delegates. They were unanimous in supporting proposals for the institution of an organization on a definitely larger scale for the collection, correlation and exchange of information regarding the mineral and metallurgical industries of the Commonwealth. Some such organization was required for the purpose of referring to specialists problems of an exceptional character arising in any territory in which geochemical methods had not so far been developed.

The examination of statistics of production and trade in mineral products would, it was felt, suggest opportunities for the greater utilization of local supplies of raw materials used in the manufacture of imported products. Such opportunities existed in several parts of the Commonwealth, but the necessary statistical evidence in respect of mineral resources was often lacking. The difficult problem of estimating unworked reserves of mineral deposits, important for all governments in times of possible emergency or interruption of ocean transport, likewise turned largely upon the need for adequate geological surveys.

General statement

The Conference reviewed carefully the position regarding the mineral resources of the Commonwealth in relation to the serious present and threatened further shortage of many important key minerals and agreed that a much increased Empire effort is required in all aspects of geology, geophysics, mineralogy, process metallurgy and in the compilation of reliable data on which estimates of present and future supplies of minerals may be made.

Recommendations

1. That a Commonwealth organization be established with headquarters in the United Kingdom to include the following functions, some of which are performed already by the Imperial Institute :—

    (a) To act as a clearing house for information, statistical and general, on the scientific and economic aspects of the mineral resources, mineral production and metallurgical industries of the Empire.

    (b) To institute, in concord with the various governments of the Commonwealth, standard methods of recording figures of production, trade and resources in mineral and metallurgical products.

(c) To promote the exchange of information regarding the estimation of mineral reserves and/or to publish estimates at suitable intervals.

(d) To provide an information service dealing with publications concerning all branches of geology, mineralogy, palaeontology, geochemistry, applied geophysics, ore-dressing and production metallurgy.

(e) To refer to suitable specialist institutions for advice or investigation, mineral problems and specimens, for the study of which facilities may not be available at the time in most parts of the United Kingdom, Dominions or Colonies; and to advise on the extension of existing, or establishment of new, institutions as may from time to time be considered necessary to meet the requirements in these respects of the Commonwealth.

2. That systematic geological survey work being the foundation of all progress in the mineral industries, in future much stronger geological organizations are essential for work in all parts of the Commonwealth.

The Conference reviewed with approval the summary, set out in the appendix below, of the essential functions of a geological survey and agreed that anything short of this programme would generally prove to be an uneconomical investment of public funds.

APPENDIX

Essential functions of a geological survey

Official geological surveys should be maintained in sufficient strength to permit of :—

(a) The development of the general geological map, which will become the guide for all prospecting activities official and private as well as for operations regarding water supply and engineering projects.

(b) The preparation of a geological map by stratigraphical geologists is not possible, without the constant reference of questions to specialists in palaeontology, petrology, mineralogy and geophysics.

(c) For the development of the mineral resources of a country to the best advantage, it is important for a geological survey department to be familiar with the statistics of production, imports and exports. From the figures of such returns the department can advise its government to direct its policy to the encouragement of industries based on raw mineral supplies, for it is obviously uneconomical to export raw minerals which might be smelted or otherwise processed near their sources, and equally uneconomical to import materials and articles which might be manufactured from minerals of domestic origin.

(d) It is essential to build up at the headquarters of a survey a reference library and a collection of reference specimens. It is equally important to maintain publications in recognized form, through

the distribution of which geological officers will get the criticism as well as the appreciation of outside scientific and technical communities.

(e) The activities of a geological survey department should be purely advisory ; but as the full list of specialists and equipment required is generally beyond the capacity of smaller states and colonies to maintain, it is desirable to federate for such advisory functions, suitable groups geographically and politically related to one another.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Sir Lewis Fermor

Sir Lewis Fermor said that he had studied the papers on subject (*k*), and had arrived at certain conclusions, some of which had been expressed by others. The most important of these could be summarized as follows :

1. Systematic geological mapping is the foundation of all geological and mineral progress.

2. There should be a correct understanding of the proper division of functions between the Geological Survey and the Mines Department of a country. It may be indicated by the respective spheres of responsibility, namely—

(*a*) The Geological Survey should be responsible for the safety of mineral deposits, i.e. for their proper working with respect to the extraction of the maximum amount of mineral economically possible.

(*b*) The Mines Department should be responsible for the safety of human life, i.e. for the administration of the country's Mines Act.

This division means that in matters of mineral policy the Geological Survey should be the adviser of the government. This is the distribution of functions that exists in India ; but in practice this distribution varies from country to country, mainly in accordance with the history of the development of the two departments. Compare Malaya and South Africa with India.

3. Mr Monture has this morning impressed upon us that in mining we are extracting an irreplaceable capital, a wasting asset. In my view, in all countries in which mining is the principal or one of the principal activities of the country, action should be taken to form an Amortisation Fund serviced by mineral revenue so that the country may still have an income derived from its minerals even after these minerals have been exhausted. This means that the whole of the revenues derived from minerals, e.g. royalties, import duties, income tax, should not be treated as a part of the general revenues available for current expenditure. Thus, in my report on the Mining Industry of Malaya made (1939) to the Government of Malaya I proposed the establishment of a Tin Revenues Amortisation Fund to be fed from the tin export duty. An alternative to some such scheme is to use mineral revenues for capital purposes to establish works or industries that will continue to produce revenue after the demise of the mineral deposits. Any government that fails to amortize a portion of its mineral revenues will be regarded by posterity as a spendthrift.

4. Governments should interfere as little as possible with the commercial aspects of mineral utilization and distribution. Thus

(*a*) there is no point in preventing the export of minerals that are in excess of a country's internal needs ;
(*b*) but if a mineral can be advantageously treated or worked up before export this should be encouraged ;
(*c*) on the other hand the wrong use of minerals in short supply should be discouraged. Thus it is short-sighted to use limited supplies of coking coal for power purposes in countries possessing vast supplies of high-grade iron-ore, as in India or South Africa. Each country has abundant supplies of non-coking coal available.

5. Mr Beard has mentioned the resolution passed by the Empire Council of Mining and Metallurgical Institutions in 1927, which was adopted by the Imperial Conference in 1930, inviting Empire countries to compile mineral and metal statistics on a uniform plan, showing the production, exports and imports of mineral products, and the available resources as far as known. Mr Beard had lamented that no result had come from this effect. He (Sir Lewis Fermor) must therefore, record that he, as Director of the Geological Survey of India, had taken the desired action, and the statistical tables required had been compiled and published in the *Records of the Geological Survey of India* [Vol. XVI, pp. 472–534 (1933)].

Professor A. E. TRUEMAN

It is agreed that a co-ordinated survey of mineral resources is necessary and I do not propose to advance further arguments in favour of such a scheme. There remains, however, the problem of how such co-ordination is to be achieved.

In the first place, any survey of mineral resources must largely depend on the work of the regional Geological Surveys. Special investigations of particular resources may be needed from time to time, but if there is to be full information of all resources and a suitable basis by which estimates can be checked, it is essential that geological mapping of all areas within the Empire should not be delayed. The relative urgency of different regions may be determined by the need of information concerning particular materials. In the course of geological mapping use must be made of new techniques whenever that appears to be desirable, and especially when the nature of the surface rocks is such that the deeper structures may not be revealed by mapping. The primary need, therefore, is for an increase in the personnel of the various Geological Surveys.

It does not appear that a scheme for a co-ordinated survey of mineral resources would necessarily involve serious modification of existing geological organizations. Whether it is convenient to have a Bureau of Mines linked with, or independent of, the Geological Survey may be a matter for local decision. So far as the present proposal is concerned it is only necessary that the local organization shall provide to the co-ordinating authority the information it requires.

The central co-ordinating department would not need to be a large

organization. It could possibly be developed in connexion with the Imperial Institute. It would be easier to establish such a central organization now than when a similar proposal was made at a former Imperial Conference, since a central office is about to be established for Colonial Geological Surveys. An essential step in the development of such a co-ordinated survey would be the acceptance by the Dominions' and Colonial Geological Surveys of a common basis for reporting estimates of materials. The compilation of data assembled for varying purposes would be of little value unless the geological data and the calculations as to probable resources were on a comparable basis.

MINERAL RESOURCES

(Department of Mines and Resources, Mines and Geology Branch)

In the years immediately following the First World War (1914–1918) considerable discussion was devoted to the mineral resources of the Empire, but apart from the compiling of the usual government statistics on production and consumption, very limited measures were taken to tackle seriously the subject in any of the Dominions or in the United Kingdom and Colonial Empire. At the Second (Triennial) Empire Mining and Metallurgical Congress held in Canada in 1927, Sir Thomas Holland, President of the Institution of Mining and Metallurgy, presented a paper entitled, 'Proposed Review of the Mineral Resources of the Empire.' In the opening paragraphs he submitted the following proposition :

'In each of the Dominions, and, if possible, in each of the larger Colonies, committees of specialists should be appointed and entrusted with the duty of reviewing for each large state or unit of area its mineral resources and smelting capabilities, having in mind the desirability of accumulating, in addition to the ordinary official statistics of production and movement, the essential data necessary for the formulation of an economic policy, as well as for obtaining the information required to institute measures designed to secure military safety.' In his paper, Sir Thomas drew many of his conclusions from the mineral deficiencies and supply problems that arose during the First World War. The story has a familiar sound to those who have had any connexion with similar problems during the past six years.

In accordance with the proposition developed in Sir Thomas' paper, the Institution of Mining and Metallurgy submitted the following motion to the Second (Triennial) Empire Mining and Metallurgical Congress, which was unanimously carried.

> 'RESOLVED, that the Council submit for consideration by the Second (Triennial) Empire Mining and Metallurgical Congress the resolution :
>
> 'That this Second (Triennial) Empire Mining and Metallurgical Congress, assembled in Canada, having discussed a proposal for instituting a review of the mineral resources and industries in each appropriate administrative unit throughout the Empire, and of the conditions affecting their development, embodied in a paper submitted under the auspices of The Institution of Mining and Metallurgy by Sir Thomas H. Holland,
>
> 'RESOLVED, that the proposal be referred to the Empire Council of Mining and Metallurgical Institutions, to be transmitted to the Councils of the constituent bodies for consideration, with a request that they will formulate their views and communicate them to the Empire Council for further action.'

At the Third (Triennial) Empire Mining and Metallurgical Congress held in South Africa in 1930, the Empire Council of the Congress resolved that all committees constituted under its resolution be requested to approach their respective governments to undertake a mineral survey on the following lines :

(*a*) reserves within the existing limits of economic production
(*b*) reserves outside the existing limits of economic production
(*c*) production
(*d*) economics of production
(*e*) mineral exports
(*f*) mineral imports
(*g*) consumption
(*h*) smelting and refining facilities.

Items (*c*), (*e*), (*f*) and (*g*) are compiled and furnished by the Dominion Bureau of Statistics. Item (*h*) is compiled by the Division of Mineral Resources, Bureau of Mines. Items (*a*), (*b*) and (*d*) apparently had not been seriously undertaken. It is these three items and especially the first two that require our immediate attention. The lessons learnt during the two world wars should have taught us that we can no longer neglect the maintaining of a continuous inventory of our mineral resources. Production figures alone are not a true indication of resources or reserves. It is necessary to know the approximate amount of ore in the ground, its grade, and its amenability to treatment. The gradual depletion of high grade deposits throughout the world and the improved methods of mineral dressing and extraction are continually changing the economic status of marginal and sub-marginal ores. What to-day may be ore of a grade or type unsuitable to mine, in five years may become producing ore. In assessing reserves on an Empire basis, it will be necessary to adopt some common denominator whereby the mineral reserves of the constituent areas may be on a comparable basis.

A few of the factors involved may now be considered.

Reserves within the existing limits of economic production are the easiest to obtain. They consist of all producing mines, recent discoveries, and deposits in which the grade is known.

Reserves outside the existing limits of economic production comprise a more complex group and require a careful classification to assess their potential value and possibilities.

This group comprises minerals that play a vital part in national defence. Chromium, molybdenum, tungsten, cobalt, manganese and antimony are examples. In normal times requirements are met from sources outside of Canada. But during two wars Canada has had to make frantic efforts to develop and utilize domestic sources of many of these metals. When the emergency passes the mines are closed down and the trade in these ores moves back to pre-war channels. A great deal of information has been gained during this spasmodic period of operation and it would appear that all this information should be collected and compiled before it is lost or forgotten.

It has been suggested that in the case of any mine closing down the

plans of the mine should be deposited with some competent government agency. This would be a valuable aid in assessing the mineral resources.

The first requirement in a review of mineral resources is an index of mineral occurrences.

This is the foundation on which to build. Then the deposits must be classified as to grade, amenability to beneficiation, location, domestic or export requirements of the ore, uses, record of technical investigations, metallurgical information, relation to world sources, etc.

Much, if not all, of this information is available, but is scattered and widely distributed. It is necessary to consolidate this information under a proper classification in order to get an accurate promise on which to compute the mineral reserves of the country.

What are mineral reserves ?

When an attempt is made to determine what are mineral reserves it is found that a simple statement is not sufficient. The term is so broad and subject to such a variety of interpretations that unless careful consideration is given to these interpretations the answer will be vague and of little value. To illustrate this point let us take a few examples.

First let us consider nickel. The general answer is, ore in sight for a hundred years or more. This is too vague, it only tells part of the story. What is required is as follows :

(*a*) Developed ore in present operating mines, grade and type known.
(*b*) Undeveloped ore in present operating mines proved by diamond drilling, grade and type known.
(*c*) Undeveloped ore proved by diamond drilling on properties not yet opened up by mining, of a grade suitable for existing economic production.
(*d*) Undeveloped ore proved by diamond drilling, but of a grade not at present suitable for production.
(*e*) Favourable areas where surface indications denote nickel occurrences.
(*f*) Geological formations which might be favourable for prospecting for nickel ores.

By this classification we can define our reserves as follows :

(i) actual reserves (item (*a*))
(ii) potential reserves (items (*b*)-(*d*))
(iii) problematical reserves (items (*e*)-(*f*)).

This in general will apply to gold and most of the base metals.

There is another group of minerals which are only spasmodically mined in Canada, owing largely to their limited extent or marginal grade. Tungsten, chrome, antimony, molybdenum are included in this group. In times of emergency these minerals assume important dimensions and during two wars they have been produced in Canada in a modest way to meet a national need.

To bring the reserves of these ores under the above classification is a little more difficult. In practically all cases the mines are not operating.

There has been gained, however, a large amount of information on these operations and the actual and potential reserves with grade and type of ore should be available in company files, and in government records, at the present time. It may not be easily available five years from now.

Mining is a wasting asset and the compilation of reserves requires a constant review. The reserves under the different classifications will vary from year to year, as new territory is opened up, new extractive processes developed and prices increased. Surface indications become undeveloped ore proved by diamond drilling ; developed ore increases or decreases ; and so on. The picture is always changing in the case of the gold and major base metals such as copper, lead, nickel and zinc. In the case of secondary metals referred to above, the situation is more stabilized and an inventory taken will probably be good for a number of years subject to additions in the lower classifications.

THE MINERAL INDUSTRY OF THE UNION OF SOUTH AFRICA *

By S. H. Haughton

In perusing the notes which follow on the mineral industry in South Africa, readers should realize that they are written by a geologist and not by a mining engineer, and that they therefore suffer from the disabilities normally assumed to be attached to that fact.

The discovery of diamonds in 1870 and of the Witwatersrand goldfields in 1886 turned South Africa from a predominantly pastoral country with a scattered white population into a land whose economy came rapidly to be based primarily on mining. According to the Union's Government Mining Engineer, the total value of the mineral output of the Union in 1944 was £122,500,000 (approximately $493,000,000 at the present exchange rates), to which gold contributed 84 per cent. The same authority stated that gold furnished some 33 per cent of the Union Government's total revenue in that year, and that it was a fair estimate to state that approximately one half of the country's population obtained its livelihood directly or indirectly from the gold mining industry.

In any review of the Union's mining activities and in any consideration of the country's future, gold mining therefore must occupy a prominent place. It is proposed, however, in this article to devote some space also to the other elements in the picture, and to consider, as far as is possible, the extent to which their relative importance may increase. It is generally conceded that the present structure is not properly balanced and that an economy based on a preponderance of a single non-permanent factor possesses potentialities of serious instability.

It should be generally appreciated that the gold mining industry in the Union has, in all probability, passed its zenith. In consequence of the increase in value of gold that came about as a result of the Government's decision to 'go off gold' in December, 1932, spectacular increases in production took place. By the end of 1940, the mines of the Witwatersrand had produced a total of nearly 350,000,000 fine ounces of the metal. To attain this total, mining of the conglomerate reefs down-dip along a strike of more than sixty miles has been effected to a vertical depth, in one mine, of 8,600 feet. Some of the older mines are no longer worked ; others are rapidly approaching the end of their expected lives and, for the present, the main producing area must inevitably give progressively lower yields annually unless other factors than those affecting production to-day act as beneficent agents.

To study means of prolonging the lives of these somewhat senescent producers is the object of a new project to be known as the Deep Level

* This paper awaits publication by the American Institute of Mining and Metallurgical Engineers.

Mining Research Institute. This is sponsored equally by the Government and the Transvaal Chamber of Mines, and will investigate the many problems associated with the mining of ore down to 12,000 feet, problems that are physical, physiological and economic.

For a number of years it has been known that outcrops of members of the Witwatersrand system (the geological system that contains the auriferous conglomerates of the Johannesburg area) were to be found at and near Klerksdorp, which lies some eighty miles south-west of the most westerly producing mine of 'The Reef.' It was presumed that the gold-bearing reefs were present somewhere along this eighty mile stretch, but they and their associated rocks were covered unconformably by more recent lavas and sediments, and early sporadic attempts to drill through this covering proved unsuccessful. From 1930 onwards the subject began to be studied seriously by geologists who, aided by geophysicists and by geophysical instruments, finally believed that they could locate the sub-outcrop of the chief gold-bearing reef over a large portion of this country. The chief gold mining companies agreed to risk money in drilling as a result of the geological advice, with the success which is probably well known to you to-day. Similarly, in the Orange Free State, south of Klerksdorp, geological and geophysical exploration, followed by deep drilling, has located payable values at a number of places over a fairly large area. When conditions for the procurement of the necessary mining machinery are easier, mines will be started, and it is anticipated that at least five large mines will, in the course of a few years, be able to take the place of some of those which are dying in the area of the hitherto main production. The decline of the industry will therefore be less rapid than had been anticipated before the accuracy of the geological predictions was proved.

One factor of major importance bears upon the future of the gold mining industry. What will be the value of gold in the 'brave new world'? It is not proposed here even to attempt an answer to this question.

In the list which is published annually of the total value of minerals produced in the Union, the second place is occupied by diamonds. Diamonds are obtained by deep mining from the Kimberlite pipes and by recovery from alluvial gravels and raised beach gravels along the western coast near the Orange River mouth. Output fluctuates somewhat from year to year and is, to a large extent, controlled. Those engaged in the industry are optimistic concerning the future both of gem stones and of industrial diamonds and base their optimism both on a deep knowledge of human nature and on a careful estimate of industrial trends.

Occupying third place in the table of values of total output is coal. In spite of recent events and of the possibilities of harnessing atomic energy for the use of mankind, coal is likely to remain an important asset to any nation. It plays an important rôle in both national and international affairs. The Union is fortunate in the possession of large resources of coal which, although they may not be of the highest quality, are by no means poor. Exploitation for the normal uses to which coal has hitherto been put has been on a modest scale compared with that of the larger coal-bearing countries of the world, and even that exploitation has not always been of optimum value to the State. It is known that the reserves of coking coal are somewhat limited and it is a matter of some concern, to

those who consider the future expansion of the Union's industries, that these limited reserves should be used for steam-raising purposes and not preserved for utilization in the production of coke for the metallurgical industry.

With such large reserves of non-coking coal, one's thoughts inevitably turn to the possibility of using this material as the basis of a chemical industry in addition to its more normal use as a source of energy. In the initiation and continuation of such an industry, use will be made of the magic of the organic chemist who juggles with atoms of carbon, hydrogen, oxygen and nitrogen as he wills. It is pertinent to point out that Governmental action, through the technical divisions of the Department of Mines, has recently resulted in the addition of large reserves to our coal figures in a hitherto unworked area. On account of the importance of coal to the future economy of the State, the Government has for some years been undertaking very detailed investigations in the coalfields of the Union. Research on coal is conducted in the Fuel Research Institute, which is financially supported by the Government and the coal owners of the Union. This Institute has been in existence since 1930, and recently its Director spent some six months in the United States studying the methods adopted there for the investigation of the nature and uses of coal.

One of the most firmly established industries, based on the utilization of minerals in the Union of South Africa, is the iron and steel industry. Prior to the war this industry was producing about one-third of the Union's major requirements of iron and steel products, but recently a large addition to the available facilities has been made and the future of the industry seems to be very bright. There can be no doubt concerning the very large reserves of iron ore of high-grade and medium-grade quality possessed by the country. Preliminary estimates place the quantity of ore carrying over 60 per cent of iron which can be easily quarried at about 150,000,000 tons, and the quantity of various types of ore whose iron content ranges from 40 per cent to 60 per cent and silica content from 5 per cent to 25 per cent at 6,000,000,000 tons. It must be understood that those figures are both tentative and probably conservative. In addition, there are potential reserves of iron ore in the form of banded ironstones containing less than 40 per cent metallic iron which have been estimated at astronomical figures. Further, there are large reserves of titaniferous and vanadiniferous ores, both in the Bushveld complex of the Transvaal and in the more ancient gabbros of Natal, whose utilization at present is scarcely a practical proposition. Limestone occurs in great abundance and the reserves of fluorspar have been intensively investigated during recent years.

Among the metals the output of which increased in the Union considerably during the war is tin. Tin mining has been carried on more or less continuously since 1905 and, except for a short period during the First World War, the concentrates averaging about 68 per cent metallic tin were exported for smelting. Conditions from 1939 onwards made it desirable for the smelting of tin to be carried on in the Union and a modern smelting plant was erected by one of the mining companies and has been in successful operation for several years. Not only have all ores derived from the Union and South-West Africa been reduced at this plant, but arrangements were made for ore to be imported from East Africa in order to swell the Union's output of metal. The total quantities produced are

small when compared with the output from the East prior to the Japanese occupation, but they are nevertheless significant.

Of the other heavy metals, the Union is well supplied with manganese and chromium. The manganese deposits vary in grade, and their exploitation has been aimed mainly at the export of high-grade ore. Beneficiation of the lower-grade ores, which have accumulated to an extent which is greater than their true proportion, will undoubtedly assist in the prolongation of the life of the main deposits. As to chromium, it is sometimes claimed that, in the pseudo-bedded deposits of the Bushveld complex, the Union possesses one of the largest chrome reserves in the world. Owing, however, to the fact that the chrome-iron ratio in the chromite molecule is higher than is normally acceptable in the metallurgical industry, such production as has taken place has been exported almost entirely for use in the chemical industry and for the manufacture of refractory bricks. The ore occurs extensively in bands which crop out near the edges of the complex and which dip towards its centre. There are two main belts, one in the west which extends for about 100 miles in strike, and the other in the east over an almost equal length. A certain amount of ore is recovered by surface stripping, but most of it by mining at shallow depths. The dip of the layers varying between 10° and 15°, mining is done by stoping from level adits or from inclined shafts, depending upon the topography of the country. Although there are variations in grade, in thicknesses of the seams, in the proportion of hard, lumpy ore to friable, and in other factors, the cost of mining is generally low. Hopes are expressed that research may produce means of utilizing to a much greater extent than hitherto this very large source of potential wealth.

Other minerals and metals whose exploitation has produced in each case a total value of more than £11,000,000 are copper, asbestos, silver, the platinum metals and osmiridium. Of these, silver and osmiridium are recovered solely as by-products of the gold mining industry. The chief copper deposits are in Namaqualand, where they are at present being exploited by an American company, and at Messina in the Northern Transvaal. Little or no expansion of this production is likely to take place. Platinum is another constituent of the Bushveld igneous complex. Platiniferous sulphides occur in a band of rock which varies in thickness from a few feet to over 30 feet and outcrops of it have been located at intervals over a distance of some 320 miles. Average values over this great length are low but in selected areas they run between five and seven cwt. per ton over stoping widths of about 30 inches through stretches measuring from 5,000 feet to 18,000 feet along the strike. Owing to the drop in price of platinum in 1930, coupled with the restricted demand, production became reduced to that of one company. Flotation concentrates here are smelted on the property to produce a matte containing copper and nickel. This matte is enriched and, together with the crude platinoids obtained by gravity concentration, shipped overseas for refining and sale. Three types of asbestos have at times been produced in the Union—chrysotile, blue asbestos and amosite. The operations of the company that produces chrysotile have been shifted from the Union into Swaziland ; but both blue asbestos and amosite continue to appear prominently in the list of minerals produced. Reserves of these are large.

A complete list of the industrial minerals which have been recorded from the Union is almost as lengthy as the catalogue of a fairly well-stocked mineralogical museum ; but many of those included in such a list are of little more than academic interest. Others are found and worked in sufficient quantity to meet either part or all of the country's own requirements or to meet requests of overseas users.

Among the latter, corundum is the best example. In spite of the development of artificial abrasives, South African corundum still finds a steady market for special purposes. Eluvial deposits have been worked since 1912 ; in spite, however, of the inducements to production incident upon war conditions, producers are experiencing a diminution of yield in the known deposits. The source-rock of the mineral is sometimes a plumasite-pegmatite, sometimes a marundite, and sometimes corundum gneiss. In no case has it been found economic to mine these source-rocks and to extract the corundum from them, although attempts to do so have been made. All corundum exported from the Union is subject to Government grading regulations. The tungsten-bearing minerals, wolframite and scheelite, have received a lot of attention during the war years. The available quantities are limited and their exploitation will depend on the price factor and demand.

The Union's requirements of mercury are now more than met by the exploitation of some cinnabar veins which were first brought to notice during a detailed geological survey of the Murchison Range in the Northern Transvaal. These veins are narrow and dip at a high angle, but it has proved profitable to mine them and to recover the cinnabar for the extraction of mercury.

There are certain other minerals produced in the Union which meet, either in part or wholly, the country's present requirements. Some of the deposits are capable of increased production, but there is no export market which would justify such increase. Mention may be made of vermiculite (of which large deposits are available), pyrites, which is produced as a by-product of the gold mines for sulphuric acid manufacture, magnesite, gypsum, talc, barytes and kieselguhr. The Union also exploits limestone deposits for the production of all its cement requirements and finds it unnecessary to import the ordinary types of building stone although some decorative stones were imported in small quantities ; soda ash is also produced as part of the country's requirements.

As is the case with other countries whose secondary industries are not the main source of wealth, development of some or all of these minerals is dependent to a very great extent on an ability to compete with other producers in countries to which the minerals are exported. The country's present aim, however, is to strengthen the development of secondary industries and to utilize, as far as is economically possible and in an optimum manner, those natural resources which it possesses, whether they have been developed hitherto or not. To assist in this aim, the Government has formed a strong Council for Scientific and Industrial Research, and it will be part of the duty of this Council to encourage research into metallurgical processes and into ways and means of increasing the utilization of the country's mineral resources.

THE NEED FOR THE SURVEY OF THE MINERAL RESOURCES OF THE EMPIRE ON A MUCH LARGER SCALE THAN HITHERTO AND FOR MORE UP TO DATE METHODS

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INTRODUCTION

STOCKTAKING of Empire mineral deposits is essential as a basis for exploitation, for strategical planning, and for possible conservation policies. There is general agreement that the scale of geological work in Australia is at present inadequate. The Australasian Institute of Mining and Metallurgy in 1944 presented a case for the establishment of a Federal Geological Survey to the Prime Minister, and Cabinet has recently approved a notable increase in staff for the former Mineral Resources Survey, to be known in future as the Bureau of Geology, Geophysics and Mineral Resources. The position is, however, still far from satisfactory in the following ways :

(i) The existing establishments of the State Geological Surveys are too small. These Surveys must continue to play an important part in all geological work in Australia other than that carried out in the Territories, by virtue of the retention of mineral rights by the States themselves.

The present establishments of the State Surveys with regard to field geologists are given below :—

State	area (sq. miles)	number of geologists
New South Wales	309,432	8 (+3 acting geologists)
Queensland	670,500	8
South Australia	380,070	6
Tasmania	26,215	4
Victoria	87,884	6 (+2 temporary consultants)
Western Australia	975,920	7

Not all of the above are available for continuous field work and, in Western Australia and Queensland, the area per working geologist is over 100,000 sq. miles. In the more densely populated states such as Victoria, although the number of geologists in relation to area is greater, the requirements of the community are also greater, and the service is in fact inadequate.

(ii) Without detriment to much excellent work that has already been done, it must be admitted that applied geological research in Australia is generally not of high quality by modern standards, especially in mining

geology. This arises partly from lack of opportunity to devote sufficient time to projects, from insufficient specialist assistance in petrology, mineralogy, and other fields, and from deficiencies in training.

(iii) The scope of investigations made by official surveys in Australia has been traditionally circumscribed ; investigation of ceramic materials, industrial rocks, and indeed of a variety of aspects of applied geology and mineralogy other than metalliferous and coal mining and underground water supply, has been virtually neglected.

I propose therefore to assume that a need for the survey of the mineral resources of the Empire on a much larger scale than hitherto does in fact exist, and will devote more attention to certain corollaries which will arise from an expanded programme and from the use of more up to date methods.

THE INTELLECTUAL BACKGROUND

Applied geological work is profoundly influenced by the general conceptions of geological thought and the standard of techniques in normal use. These afford the background of field and laboratory studies and exert a major influence on the achievement of results. In the discovery of ore bodies in known mineral fields, for instance, the geologists' ideas as to ore genesis and structural control of ore deposition are deeply involved. It is unnecessary to stress the value of training and skill in work of this kind, for it is well known that where one man may fail, another may succeed.

This at once raises the general question of the availability within the Empire of experienced and able geologists in all fields of applied geology, especially since our experience in Australia is that the supply of first-rate geologists is far too low even for existing needs. Our teaching and research institutions are, therefore, immediately brought into the picture as essential units in the projected expansion and of these it may be said :—

(i) Increased pressure on teaching staffs is already so great in the post-war period that research must eventually suffer. Staffing and technical facilities of the Australian University Departments of Geology are too restricted to afford proper advanced training for significantly greater numbers than they have handled in the past, and must be increased and strengthened. The inspiration of foreign travel is likely to be denied many members of staff during the coming years unless financial aid for this purpose is provided. No satisfactory scheme for exchanges of staff between Empire universities or even within Australia itself has yet been devised, and much remains to be done in smoothing out administrative and financial difficulties attendant on such exchanges.

(ii) Research in geology and its sub-sciences in Great Britain has of late years made a disappointingly small impression on the general body of advanced overseas work and has not provided the looked-for stimulus to the technical aspirations of Empire geologists. As far as Australia is concerned, it must be said frankly that many eyes are turned to the United States as a possible training ground for post-graduate workers and as the main source of research data, rather than to Great Britain or to Australian institutions themselves. Our students are raised, at

least in their higher years and especially in economic geology, mineralogy, and structural geology, on a diet of foreign textbooks, and the British journals publishing important research papers of interest to the geologists of other countries are appallingly small in number and equally so in content. Many Australian authors now publish their more important works in American journals because of inadequate facilities in Australia and Great Britain. The number of British geologists visiting Australia, or working there for any considerable time is also lamentably small. Thus, and also because of the high standard of geological research in America to-day, an orientation away from Great Britain of Australian, if not of other dominion and colonial geologists, is undoubtedly being brought about. It will be obvious that this orientation is not in line with the ideal of collaboration among Empire countries in scientific work, and clearly the position will not be remedied without a strong move on the part of those countries to re-establish intellectual contact among themselves on the realistic grounds of eminence in research and adequacy of publication and liaison. A strong lead from Great Britain is earnestly to be desired.

REQUIREMENTS FOR FIELD SURVEYS

Australian experience is that restrictive pressures are from time to time put on Geological Surveys (*a*) to reduce staff in the interests of economy, and (*b*) to devote practically all their attention to economic mineral deposits with a view to producing immediate results as a justification for the existence of the Survey. Such pressures naturally have an adverse effect on standards, and anything this Conference might recommend regarding the functions and desiderata of geological and mineral surveys would afford valuable support to those who must not only plead for expansion, but also argue against contraction of their staffs. I therefore refer to the following points :—

1. Necessity for revision of geological mapping

The fallacy behind the conception of a 'completed' geological survey is shown by experience, and a Victorian example may suffice as an illustration. Geological maps on a scale of 2 in. = 1 mile had been issued by the Geological Survey of Victoria for most of South Gippsland, but bauxite is not indicated on any of these maps. Recent prospecting has shown that large bodies of commercial bauxite exist, with numerous and widespread outcrops—sufficient to form the basis for a local aluminium industry.

With advances in technology, new uses are found for rock types that normally would not be distinguished on geological maps ; previously valueless minerals become sought after, and special searches may be required for minerals containing rare elements. Thus there is need for continuous revision of geological mapping, although the older maps are invaluable as a guide to likely localities for materials newly coming in demand.

2. FUNCTIONS OF FIELD SURVEYS AND THEIR RELATION TO STAFF REQUIREMENTS

The chief functions of field parties are (*a*) prospecting, (*b*) survey of producing fields, (*c*) regional geological mapping.

(*a*) *Prospecting* has often been regarded as outside the scope of official geological surveys, but this is one sphere in which considerable expansion must be envisaged, because

(i) mineral deposits are coming more and more under direct government control
(ii) recently developed methods of prospecting call for the use of facilities far greater than those available to small prospectors or even companies
(iii) in many regions, visible ore bodies have been discovered already, so that geophysical, geochemical, and advanced structural methods must be used to locate new ore
(iv) in non-metallics, e.g. clays, ochres, and industrial rocks, a great and, in Australia at least, little-explored field awaits development.

(*b*) *Survey of producing fields.* This is of high importance, and the scope of official surveys should be widened to include interpretation as well as recording of factual data. Official reports have traditionally avoided hypothecation, but no one is more competent than the man who has recorded all the facts to give an interpretation.

(*c*) *Regional geological mapping.* Projects aiming at the discovery and exploitation of mineral deposits *sensu stricto* have, in many instances in the past, failed because of a too rigid interpretation of function. Without specific reference, it is possible to recall examples from Australia in which the short-sighted view of concentrating on immediate results has resulted eventually in impotence and waste. Opportunism should have no place in a planned programme of mineralogical-geological research, and I cannot envisage an expanded investigation of the mineral resources of the Empire without concomitant expansion of geological survey. Some concrete grounds for the need of geological surveys both regional and detailed, however, may be briefly noted.

(i) The exploitation of all bedded mineral deposits, many lode deposits, and of underground water requires a basis of stratigraphical and structural knowledge.
(ii) For engineering geology, soil survey, and town and country planning, regional as well as special geological surveys are required, and in the opinion of many geologists such applications of the science may in the future assume an even more important place in our communities than mineral exploration.

REQUIREMENTS FOR LABORATORY INVESTIGATIONS

The provision of laboratory facilities, especially to the staffs of the smaller official Surveys, is a difficult problem, but is essential for the success of an expanded programme along modern lines. The establishment of adequate genetic and structural conceptions in many mining fields is not possible without much more petrological and mineragraphic

work than has been carried out normally by small surveys, and the value of mineragraphic study in problems of ore dressing and recovery is now too well realized to need stressing. In addition, the usual palaeontological, assay, chemical, and cartographic facilities must be provided. How such services will be established is a matter for determination in individual cases; in Australia the amount of specialist assistance available is even less adequate than are the field staffs. The Council for Scientific and Industrial Research provides a mineragraphic and petrological service of very high calibre but with a staff of only two. The Commonwealth Bureau of Geology, Geophysics and Mineral Resources employs one palaeontologist, and the State facilities are on a correspondingly low level.

RECOMMENDATIONS

In so far as Australia may be concerned in collaboration for increased geological and mineralogical services within the Empire, the following recommendations are made:—

1. That considerable expansion in British and Australian research in pure and applied geology and mineralogy is required. It is suggested that the teaching institutions should concentrate on fundamental research, however, without neglecting investigations in the applications of geology and its sub-sciences, and that the Geological Surveys and 'Councils for Scientific and Industrial Research' (or sister bodies) should concern themselves mainly with applied work without neglecting the fundamentals.

   Some centralization of research within each country is desirable so that post-graduate students and other trainees could obtain most of their advanced specialist tuition in a few institutions, and also to avoid dissipation of material resources.

2. That increased facilities for overseas study within the British Empire should be provided by the institution of a system of exchanges of personnel and increases in travelling scholarships, and that university staffs should take a major place in such a system.

3. That improved facilities for geological publication are required, especially for overseas workers to publish in British journals.

4. That an authoritative statement should be prepared pointing out the necessity for increased geological and mineral resources surveys. This statement should also contain details of the short and long-term functions of such surveys and give an indication of the type of establishment and administrative arrangements that are desirable.

THE NEED FOR A CO-ORDINATED SURVEY OF THE MINERAL RESOURCES OF THE EMPIRE AND FOR OPERATIONS ON A MUCH LARGER SCALE THAN HITHERTO

By Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S.

I. ORIGIN OF THE BRITISH SURVEY POLICY

In 1835 the Geological Survey of England was founded at the suggestion of the Master-General of Ordnance, and De la Beche, the first Director, concentrated his initial efforts on geologically colouring the new ordnance maps of the south-west counties, followed by those of South Wales, where the maps would be of direct assistance to the mining industries. The economic aspects of the new science and the preparation of geological maps remained the dominant characteristics of the work until De la Beche died in 1855, when Sir Roderick Murchison succeeded him and laid special emphasis on the purely scientific problems of geology,* without, however, changing the policy of extending the one-inch geological maps. Murchison was followed by Sir Andrew Ramsay, a brilliant field man whose special bent was revealed by an extraordinary out-turn of geological maps during his ten years of office.

Then, in 1882, came Archibald Geikie who completed the one-inch geological map of England and issued a number of stratigraphical memoirs to supplement those that had been previously issued on a regional basis with their corresponding maps. Work of this class and the introduction of the new branch of petrology were among the prominent features of Geikie's term of office between 1882 and 1901, when he devoted his surplus energies to the Royal and Geological Societies of London, both at that time being devoted to pure science as the Geological still is.

This introduction helps us to understand how the policy followed under these distinguished Directors in the United Kingdom affected and to some extent made fashionable the programmes of Survey work in British lands overseas ; for W. E. Logan was selected in 1842 from the British staff to organize a Geological Survey for Canada ; Selwyn went out in 1852 for a similar purpose to Victoria and thereafter in 1869 was transferred to succeed Logan as head of the Survey in Canada. Thomas Oldham was selected in 1850 to organize a Geological Survey in India, to which he attracted as his assistants several of his old colleagues on the Irish branch of the Survey. Oldham was indeed another De la Beche, not a mere disciple : he started the general geological map of India, but commenced

* 'He had little interest in the economic applications of geology which for De la Beche had been of prime importance.' J. S. Flett, *The first hundred years of the Geological Survey of Great Britain*, 1937, p. 58.

field work on the peninsular coalfields, extending the classification of formations from that datum both upward and downward on the stratigraphical scale. It is difficult here to resist the temptation to describe Oldham's remarkable personality and work till his retirement in 1876; his well-balanced regard for every phase of geological activity—economic, scientific and educational.

It is necessary, however, for the purpose of my argument, to remind you of the contemporaneous influence in this country of the Geological Society of London. It was then and still is limited to studies of 'pure' geological science, which from the first to the third quarter of the nineteenth century occupied an outstanding position among the sciences, and was indeed a matter of keen popular interest from the time when John Playfair, the apostle of Hutton, led the attack on the fantastic theories of Werner till Huxley, the apostle of Darwin, carried on the campaign after the publication of the *Origin of Species* in 1859. Names like Lyell, whose *Principles* appeared in the 'thirties, Buckland at Oxford, Sedgwick at Cambridge and others of like stature, were as prominent in English table-talk then as Monty, Alex and Ike, for other good reasons, are to-day. No wonder, therefore, that Geikie, the protégé and biographer of Murchison, regarded pure geology with a reverence so profound that to him, official activity for economic ends would introduce the Geological Survey to an atmosphere in which the brightness of pure science might become murky by the smoke of commercialism.

Metallurgical heavy industries flourished in this country during most of the nineteenth century on raw materials of home origin, which were relatively few and simple, well known in origin and limited to a few districts already surveyed in the time of De la Beche. Science and industry seemed then relatively independent of one another.

The adolescent age of natural science was followed by a long and relatively dull period of descriptive work ; but, among seniors like Geikie, quite naturally, memories of the heroic period still survived ; and in the Royal Society, for instance, applied science was still looked on askance till well after the present century started. Geikie, as Secretary for five years from 1905 and as President for another five, set the standard for geology, and that explains what happened in India.

II. REORGANIZATION OF THE GEOLOGICAL SURVEY OF INDIA

In 1903 I was asked by Lord Curzon, then Viceroy in India, to undertake a reorganization of the Geological Survey with the object of devoting its main activities to the development of India's mineral resources. So when, five years later, results began to show, a Royal Society Committee, under the direct influence of its senior Secretary and prospective President, protested against such dangerous departures from the old orthodox survey policy of map-making mainly for scientific purposes.

We have gone through two world wars since then and now at the end of the second one, I have been asked by the same Royal Society to open this 'discussion on the need for a co-ordinated survey of the mineral

resources of the Empire and for operations on a much larger scale than hitherto.' 'The wheel is come full circle,' and indeed one would not be surprised now to see in the near future the names of distinguished mining engineers or petroleum technologists appearing in the annual list of newly-elected Fellows.

The heresy of which I was supposed to be guilty for seven years from 1903 faded before the simple facts; for most of the policy which incurred blame in high quarters and commendation from more charitable sources was little more than a resurrection of the policy originated by Thomas Oldham and still regarded as a healthy, well-balanced life for any Geological Survey instituted for the main purpose of serving the requirements of the technical industries.

In reality no great change had occurred in the work of the Survey officers; but at headquarters the Director brought together the statistics which had hitherto been recorded by local governments in various unlike units; he reduced them to standard tables, compared them with world figures, and, with their help, published the first quinquennial review of mineral production and trade for India. This new feature in the Survey publications attracted the interests of the mining community, with the formation of the Mining and Geological Institute of India, the criticism and ultimate revision of the rules for the grant of prospecting licences and mining leases. The *Records*, published quarterly up to 1895, having then been discontinued for want of papers, were revived in 1904 and rapidly went 'out of print' by sales to the public. Altogether, a new spirit stirred the old department from its lethargy, specimens and information came in from miners and prospectors; and, as one result of the friendly intercourse between the two main sections of the newly formed Institute, the usual confusion between the Geological Survey and Inspectorate of Mines disappeared by recognition of the fundamental distinction between mineral economics and mining exploitation—the one a natural study for specialists of the Geological Survey; the other a form of civil engineering underground conducted by mining engineers under the general supervision of inspectors, who were appointed for humanitarian, not economic purposes.

The new activities which became naturally conspicuous among the Survey publications in India were never, however, allowed to divert stratigraphers from the old-established duties of extending and revising the general geological map, with the publication of corresponding regional memoirs, whilst palaeontological monographs, based on fossil collections, were published by specialists, some within the Department and some by recognized authorities in Europe.

Other accessory functions naturally forming part of geological survey work in an undeveloped country were supported by the Survey officers—active interest in geology as a subject of university education which creates a new market from which to draw locally trained recruits, and the organization of museum collections as a contribution to public education and interests.

Here then you have the menu of the Geological Survey of India from 1903 onwards: it is little more than a filling in of the programme outlined and initiated by Thomas Oldham over half-a-century before.

It might not be unfair to say that the difference between the Geological

Survey of India in the last quarter of the nineteenth century and the first quarter of this is roughly this : in the first of these two periods the Survey mechanically recorded economic data in its published memoirs and provided information whenever required by government officials and the public ; in the second period the obvious lessons were also published, whilst new lines of policy were suggested for government intervention or support. The Department passed from the passive to an active mood.

III. RESPONSE TO UNFORESEEN DEMANDS FOR RAW MATERIALS BY NEW INDUSTRIES

By way of illustrating the assertions which have so far been made regarding the proper functions of a geological survey, we might consider the kind of questions which require early and authoritative answers when a technical departure demands supplies of some new or unfamiliar mineral ; and this has arisen conspicuously in Great Britain with the successive discovery of new alloys, each displacing its predecessors for efficiency.

Following Hadfield's discovery of manganese-steel in the eighties, other ferro-alloys followed in rapidly increasing variety and the metallurgical industries in Great Britain then demanded a greater variety and larger quantities of raw materials than could be obtained in this island. They had to go overseas for supplies. As the result of recent technical inventions, inspired noticeably by war necessities, demands have been created also for mineral raw materials which were previously regarded everywhere as of little more than academic importance.

Among these the discovery of new alloys will continue to be conspicuous in the near future, for metallurgists are rapidly passing from the old trial-and-error methods to the recognition of controlling laws which will enable them to forecast more reliably the physical properties and probable usefulness of new alloys. They will tend to keep ahead of the economic mineralogists who have first to establish in each country deposits of industrial value and thereafter to produce them in a form suitable for the use in the arts. Both may be slow processes. Consequently, only those countries which have maintained geological surveys in sufficient strength, with a wide variety of specialists, will be prepared to take advantage of such advances in technology. In any event, geological survey work will always tend to lag behind industrial demands just as a dictionary lags behind its spoken language.

We might halt here to consider as an appropriate illustration, the surprise which was caused just before the war started by the discovery of a new alloy of copper and beryllium which had a tensile strength six times that of copper and produced springs which showed no signs of fatigue after many millions of vibrations. The value of this discovery in the manufacture of instruments suggests an advance comparable to that which followed C. V. Boys' production of quartz fibres sixty years ago.

What bearing have these statements on our present thesis—the importance of extending and co-ordinating our knowledge of our mineral resources ? It is simply this : the Director of the Geological Survey, not the Inspector of Mines, should take immediate action to see if sources of beryllium exist

in his territory. He knows that the chief source of beryllium is and probably will always be the mineral beryl ($Be_3Al_2Si_6O_{18}$), which contains well under 5 per cent of recoverable metal. Hitherto it has been a conspicuous exhibit in our museums because its common form occurs as large hexagonal crystals, and its transparent gem form is the very rare and much prized emerald.

But the beryl that we know is found as an exceptional constituent of pegmatite veins traversing granites and granitoid gneisses, which cover wide areas in Canada, Brazil, Central Africa, Peninsular India and Australia. That much we know of the habits of beryl and therefore where we might search for it with some distinct prospects of success. But within the great areas occupied by the granitoid gneisses, the search for valuable pegmatites is purely a mechanical process, requiring the keen eye of trained mineralogists.

So far the world has produced little more than about 200 tons of beryllium per annum ; but the search for pegmatitic granites is worth while because they sometimes contain other valuable minerals which have habits similar to those of beryl—micas and ores of tin, tungsten, columbium, thorium and uranium. We want therefore more mineralogists and improved as well as increased knowledge of the habits of such minerals which have recently become of economic as well as vital military importance.

IV. THE COMMONWEALTH PICTURE

Before Hadfield's time, as I have said, Great Britain could produce most of the mineral raw materials wanted for her technical industries ; but soon after, when this country was still the chief industrial area of the Commonwealth, there arose the dangerous situation of being dependent on overseas' supplies of aluminium, chrome, copper, iron-ore, manganese, mica, nickel, nitrates, oil, tin, tungsten and other minerals for which efficient substitutes are unknown. Obviously, it is desirable to make each large territorial unit as nearly as possible self-contained, although we can never get advantages equal to those enjoyed by the United States and the still larger Soviet territories, within which there are no fiscal fences to be negotiated, and raw products can be assembled at suitably placed industrial centres without the dangers which may follow transport over long ocean routes.

The British Commonwealth is composed of widely scattered units and there must consequently arise two competing policies—a continuation of the old-time habit of assembling raw materials for the industrial requirements of Great Britain, and the development of new technical industries so far as possible within each Dominion and Colony. The change over is inevitable and desirable for reasons of economic advantage as well as military security ; for it is obviously wasteful to transport to great distances large quantities of the useless constituents of raw mineral products ; and each territory of origin has the right to benefit by every practicable stage in mineral dressing and ore-smelting. India and the Dominions have already made considerable progress in this direction ; and in all of them the progress toward self-sufficiency can be assisted effectively by the development of their Geological Surveys with modern methods and on more extensive scales.

V. MINERAL STATISTICS

If the ultimate object for maintaining a geological survey is the local development of suitable industries, one important source to search for 'tips' is likely to be the officially published statistics. As stated already, every wise Government wishes so far as possible to save the cost of imported manufactures by utilizing its own raw materials. It is somebody's duty therefore to find out whether the country can produce the necessary raw materials of the right kind in sufficient quantities to replace by local manufacture materials and articles which are habitually imported. To detect and call attention to these opportunities is possible most easily by the economic mineralogist who handles mineral statistics.

For another reason also the problem of handling mineral statistics is suitably a function of the Geological Survey, for unfamiliarity with mineral terminology leads to dangerous pitfalls for the pure statistician and produces misleading conclusions. The politician may quote statistics for his own purpose and has been known to risk some horrid pitfalls. As Antonio said of Shylock's apparently altruistic bargain, 'the devil can cite Scripture for his purpose.' Two simple illustrations within my own experience are sufficient to show the importance of providing for an expert examination of the crude returns with which the statistician builds his totals. Over forty years ago, when searching for suggestions to guide the economic activities of the Geological Survey of India, it seemed wise for the reasons already given to examine in the first place the figures for external trade. Among various surprises it was noticed that iron-ore was being exported from Karachi, which seemed most unlikely from our knowledge of the mineral deficiencies of Western India, until it was realized that chromite, being worked in Baluchistan, was probably reported to the Karachi customs officers as 'chrome iron-ore.' The second instance was another example of statistics which might convey no ready mental impression to the pure statistician. It was noticed that although much mica was used in the country for special purposes, India was also exporting far more mica than, according to another chapter of the annual summary, was being produced in the country.

The second discovery led to the detection of illicit practices which only the mineral economist would readily detect. And other such anomalies of the sort ultimately led to the Government's decision to arrange for local returns to be 'vetted' by the Geological Survey before being passed on to the Director-General of Statistics for incorporation in his published tables. Similarly, critical analysis of the figures published by other countries suggested the institution of discreet inquiries. It became evident, for instance, that the Japanese authorities showed some, but not quite sufficient, degree of mineral intelligence when they suppressed all information about the smelting of aluminium in Japan, but naïvely returned import figures for cryolite which is used for no other purpose and is obtained only in Greenland.

Everyone is aware of the importance of statistics as guides to policy, and most people are aware of their dangers ; but mineral statistics have their own peculiar problems which have not yet been solved by successive conferences since the Imperial Mineral Resources Bureau was founded after

the end of World War No. 1. Its successor, the Mineral Department of the Imperial Institute, has regularly published figures for production, exports and imports which can be relied on for limited purposes, because the figures received are reduced by mineral specialists to standardized units. But the value of the Department to those who are interested in mineral developments is still limited by want of returns issued for values, for metallurgical operations and for other phases of the mineral industries throughout the scattered parts of the Commonwealth. Canada seems to have organized the most complete system of any of the Dominions and so was able to provide the Ottawa Conference of 1933 with a full review of the results of that and previous discussions.

Evidently the fourth clause of the Atlantic Charter will remain nothing but a memory of pious but sterile hopes until the United Nations Organization is entrusted with the power to collect and publish reliable statistics regarding what ' raw materials of the world ' are needed for the economic prosperity of each national unit as distinct from those desired for purposes of military aggression. One thing ought to be said and repeatedly published —that the nationals of all countries have hitherto had the same opportunities as the British people in obtaining the mineral raw materials of the Commonwealth.

Members of this Conference will probably find it difficult to persuade their government authorities to realize that the control of mineral statistics is a proper function for a geological survey department. However, it has been tried in India and found to be fertile of suggestions, both to the official body and to private workers, who, because of their numbers and freedom may be as valuable as Survey officers in discovering new mineral deposits. Oldham seems also to have started the collection of statistics, but presumably was told by government to shut up, as he was also told to mind his own business when he urged the extension of the East Indian Railway well beyond Raniganj which was its limit in his time.

VI. ADVISORY *versus* EXECUTIVE FUNCTIONS

Until recently the average administrative official has been unable clearly to realize the effect of specialization on geology as on other sciences. Geologists have been sent out in ones and twos to survey large colonial areas and to give information on their resources in oil, coal, ores and other useful minerals ; to deal with the problems of water supply and civil engineering projects ; to be their own palaeontologists, mineralogists, petrologists and mineral chemists. The geologist may be a reliable authority on one or perhaps two of these branches of his subject ; and, if so, he is likely to be a public danger when he gives advice on any of the others.

Financial limitation is the usual excuse for this false economy. There is however a minimum limit for a geological survey unit, below which its cost to the colony or state becomes merely a waste of public funds and a contributory cause of delay in the development of its natural resources. That the Empire has developed its mineral resources as it has done so far helps one still to believe in the existence of a wise and benevolent Providence.

It is impossible for every colony or small state to invest in the full variety if not the numbers of specialists employed by a government like that of the United States since the foundation of its Federal Survey in 1879, but India and the Dominions can afford it and everyone except Australia has now an organization to supersede or co-operate with the provincial surveys. Similarly, it should be practicable to establish a full-scale survey for geographically related groups of colonies like those of East Africa, West Africa, the Malayan and the West Indian regions.

There is in all distinct administrative units a tendency for officials as well as politicians to clamour for unqualified local control, forgetting the fundamental difference between the requirements of the advisory and executive functions. For advisory work it is desirable, for the sake of economy, to centralize and so be able to provide the required variety of specialists. For executive functions, in which promptness and regard for local susceptibilities are necessary, decentralization has an obvious advantage.

A geological survey is essentially an advisory body, and its modern developments have gone far beyond the old-time hammer-and-compass practice. Recent advances in applied geophysics and aerial photography for example have provided instruments which governments have been slow to understand; and, because of their expense, slower to adopt for mineral exploration.

Many other advantages arise from the federation of relatively small units for geological survey work in the Colonies, such as (i) forecasting the demands for recruits without risk to the budget of any one colony. This encourages university students to turn in good time to geology with some confidence as candidates for appointments; (ii) the maintenance of authoritative publications which enable a Survey to build up its reference library by exchange with foreign institutions; (iii) the publication in a recognized journal of reports submitted by survey officers brings them credit as well as criticism from outside specialists; (iv) a large service provides prospects of promotion for those able officers who wish to avoid blind alleys and might therefore be tempted to accept offers from mining and oil companies who know the value of seeking advice from specialists.*

VII. EDUCATIONAL WORK

If local and colonial governments will be wise enough to restrain their constant desire to have scientific officers at their own beck and call and will unite with their neighbours to build up an efficient service for advisory work, it will be possible for geological survey officers to be seconded for short periods to teach geology in a suitably placed college or university, where a museum can be established for the safe keeping of reference specimens and the display of collections for general public education.

This by-product of survey work brings its own reward by encouraging

* Within an hour of writing these two paragraphs I opened the latest issue of *Nature* of March 16 to find an advertisement by a 'major oil company' asking for a micropalæ ontologist specialized in ostracoda and another for foraminifera. A wise oil company does not spend £50,000 or more in drilling for an oil-pool without evidently first getting precise information about its position and depth.

amateurs to collect specimens, fossils, rocks and minerals, thus adding to the observational value of the survey staff. Senior and advanced students who pass through the geological classes of university standard create a recruiting market, either after special study-leave to other lands, or by immediate appointment to subordinate posts according to their qualifications. Some will be suitable also for service with local mining companies and prospecting syndicates.

Much expense and unnecessary travelling will be saved by survey officers if, when in the field, duplicates of specimens are collected for donation to colleges and senior schools. For this again geological students can be profitably employed. Even in these accessory matters Oldham had foreseen this educational value of the Geological Survey of India. Lectures were given by H. B. Medlicott to young engineering students at the Roorkee College, and through Oldham's influence a fine Museum at Calcutta was built for the proper display of the scattered natural history and Survey collections. But a part-time professorship in the Calcutta University held by a Geological Survey Officer was not established till after I went to India in 1890 ; later, two others of the same sort were established at Madras and Poona.

VIII. BRIDGING THE GAP BETWEEN ADVICE AND ACTION

If it be wise to include within the functions of a geological survey the list of activities described in this note and as undertaken by the Geological Survey of India, what official machinery is still necessary to translate information and advice into action ? Clearly it is not properly the business of the Inspectors of Mines, whose work, like that of the benevolent but watchful policeman, is dominantly humanitarian. They have to see that conditions of work underground are in accordance with the provisions of mining legislation. For this purpose they also collect statistics of production, of employment and of accidents. Officially, however, they are not interested in mineral economics.

The Inspectors also deal with mines which are already operating, not with exploration for new deposits or with prospecting operations to test their exploitable value. Hitherto, the usual practice in British territory as in most foreign countries has been to publish the information obtained by the Geological Survey and then to leave the rest to private enterprise, with naturally very variable and unequal results.

In founding the Mining and Geological Institute of India my hope was that the gap between information and prospecting enterprise would thus be sufficiently closed ; for successful mining companies naturally look out for further opportunities to increase their reserves. My hope was not disappointed, for the Institute afterwards had to incorporate the word *Metallurgical* to recognize the change in its membership due to the development of related industries which naturally followed. In the Dominions there has been a similar growth of compound institutes—the Canadian and the Australasian Institutes of Mining and Metallurgy, the Chemical Metallurgical and Mining Society of South Africa. These in 1923 joined five other Institutes in this country to form an Empire Council and they hope to hold their fourth Congress here in 1948.

We have recently had a striking example to show the want of some machinery in this country to bridge the gap between knowledge and action regarding our mineral resources. The information published long ago in full detail by the Geological Survey of Great Britain in maps, sections and memoirs had been in effect lying idle for many years when a successful oil company, with the help of new geophysical methods, undertook prospecting operations, and finally succeeded in obtaining oil in quantities sufficient to repay their expenses, with the prospect of earning still larger profits. Fancy, our Director of the Geological Survey asking the Treasury for £3 to £4 million to prospect for oil in Great Britain !

The Soviet Government followed a quite different policy in training large bodies of geological specialists and undertaking prospecting operations on a large scale at public expense. They just followed the obvious logical inference that five-year plans for industrial development must remain sterile without having available a sufficient and sufficiently varied supply of raw mineral products. The Soviet Government decided not to wait for private enterprise. Their ' plans ' however cannot be imitated outside, unless preceded by a similar political revolution. But this Conference cannot be expected to discuss that question with any hope of reaching unanimity in one session !

Meanwhile, we have it in mind and hope to assist Dominions and Colonies of various kinds and in different stages of political and industrial development. In some we have politicians who, when relatively harmless, merely follow political ideals, and we have also efficient bodies of permanent civil servants whose official habits naturally and properly tend more to restraint than enterprise. And these conditions, with their gradual modification in the near future, will naturally affect our discussion of this item in our agenda defined as ' the need for a co-ordinated survey of the mineral resources of the Empire and for operations on a much larger scale than hitherto.'

NEED FOR A SURVEY OF THE MINERAL RESOURCES OF THE EMPIRE ON A MUCH LARGER SCALE THAN HITHERTO AND BY MORE UP TO DATE METHODS

By Dr M. S. Krishnan and D. N. Wadia

PRESENT POSITION

Deposits of useful minerals and rocks have been worked in India for many centuries, but generally in a small way. Only during the present century has intensive search been made for them and large scale operations started in order to supply the raw materials for indigenous and foreign industries. In several cases the existence of old workings has proved a guide to further work, as for example on gold, copper and lead-zinc deposits. In the case of iron ore, the ancients were content with exploiting small, easily accessible deposits with no particular reference to grade or richness. Other minerals like chrome ore, barytes or high grade manganese ores found no use and thus remained altogether unworked.

The influence of European countries on India in large-scale mining, smelting and processing began to be felt only during the present century, which saw the gradual expansion of mining and industrial activity in India.

The position at present is that the great majority of important mineral deposits have already become known and some of them exploited to a limited extent. It may be said that spectacular new finds are improbable in future, though workable deposits of petroleum and non-metallic minerals of some importance explored by the application of geophysical methods may yet be discovered.

LACK OF DETAILED PROSPECTING

Though the existence of numerous ores and industrial minerals is known, the great drawback is lack of detailed prospecting concerning their size, extent in depth, variation from place to place and grades available. Doubtless there is much useful information available in the files of the private interests actively engaged in exploiting them but not known to the Government except perhaps in a general way.

The official agency charged with the investigation of mineral deposits is the Geological Survey of India, but so far (at least during the present century) it has directed its energies largely to scientific problems and geological mapping in view of its very limited and inadequate staff. Before World War II, the only systematic search undertaken was with reference to manganese ores and bauxite, and a drilling campaign in a limited part

of the Singhbhum copper belt in Bihar. Mineral deposits encountered during field geological surveys of mapping were, however, recorded but no effort was directed towards investigating them in full.

NEED FOR AN ADEQUATE ORGANIZATION

Because of the demands created by World War II, and of the realization that the security as well as prosperity of the country is bound up with the proper utilization of her natural resources (and especially minerals), the emphasis is now being shifted to mineral exploration and development. As a result, plans are under consideration for an expansion of the activities of the Geological Survey and for providing this organization with the necessary facilities. The Government of India has now sanctioned a considerable increase of personnel, from less than 30 before the war to about 150. Measures are also being taken to improve geological and mining education in the country and to impart a practical bias to it. It is expected that, in the course of a decade, there would be a competent and fairly adequate staff to meet the needs of the mineral industry contemplated by the Government.

SUGGESTED PROGRAMME AND ORGANIZATION

The programme of work of the Geological Survey will henceforth include a systematic investigation of the mineral resources of the country, both in metallic ores and non-metallic minerals. The investigations should include not only the location of deposits but also the collection of adequate data regarding their extent and other characters including appraisal of qualities and quantities available and of the best methods of winning and utilizing the minerals. A programme of geophysical survey of certain regions is to be undertaken.

KNOWN AREAS AND ANCIENT PITS, ETC.

As further steps in this direction, the mapping of all known mineral-bearing areas should be undertaken on a large scale, accompanied by prospecting and sampling. In many cases it would be necessary to prove the deposits by exploratory drilling. All old pits and shafts should be carefully re-examined, wherever it is known that these are due to former mining activity decades or centuries ago. That such re-examination will be worth while is shown by the fact that the present gold mines of Kolar and Hatti and the copper mines of Singhbhum have been developed by following the relics of former activity. The lead-zinc mines at Zawar may be another instance.

GENERAL AND AERIAL MAPPING

Simultaneously with these activities, general geological mapping of the country on one inch to a mile and larger scales should go on since this will lead to the discovery of all useful deposits, of whatever size. There

are still large areas of India which await modern mapping, including patches which have perhaps never yet been visited by any geologist. This programme would be greatly helped by aerial mapping, using the best modern technique, as this would aid in locating particular regions for early and detailed studies.

Another important step would be the routine employment of the geophysical—gravitational, seismic, electric and magnetic—methods by specially trained personnel. Some of these methods have been used in India in recent years by two oil companies, the Kolar gold mining interests and the Copper Corporation in Bihar and, to a very limited extent, by the Geological Department of the Mysore State. Since the efficacy of these methods, at a comparatively small expense, has been proved lately in Arabian desert and elsewhere, in the location of important oil-bearing structures, electrically conducting and magnetic ore bodies, and in water-finding and rock-foundation problems, their use on a much larger scale will be fully justified.

STAFF FOR FUTURE WORK

It is not easy to visualize at present the details of the organization necessary for carrying out mineral development adequately. We may, however, suggest that the Geological Survey of India should, within the near future, consist of some 200 geologists for mapping and mineral exploration, 40–50 geologists for investigating hydrological problems (ground water, location of dams, etc.) and some 20–30 geophysicists. In organizing this body the experience of other countries in the Empire and outside should be drawn upon.

LABORATORY FACILITIES

The planning of the survey of mineral resources will be incomplete without the provision of facilities for chemical and petrographical laboratory research, beneficiation and concentration, and research towards utilization of the raw materials. Many of these facilities as well as an agency for giving free advice and information on mineral technology are to-day almost non-existent. Such functions, however, are performed by organizations such as the U.S. Bureau of Mines and the Canadian Mines Branch of the Department of Mines and by the Imperial Institute, London. For our present purpose it is immaterial whether these laboratories are under the direct control of the head of the Geological Survey or under separate control, but the need for these facilities cannot be gainsaid. The Canadian model where the Geological Survey and Mines Branch are under a unified direction would seem worthy of adoption.

While the above functions relate to mineral research there are also others which are closely allied, viz. those relating to *improvement of mining*—mining methods, ventilation, safety, use of explosives, laboratory research on mining technique, etc., will be necessary in order to establish a prosperous and efficient mining industry. Facilities for this work also will have to be provided.

INDIA'S PLACE IN EMPIRE (AND WORLD) MINERAL ECONOMICS

Position with regard to industrial minerals

Though far from self-sufficient, India is reasonably well endowed with minerals. Attention is called to important surpluses and deficiencies below.

(i) Minerals of which our exportable surplus can supply world markets :—

iron-ore
titanium-ore
mica

(ii) Minerals of which our exportable surplus forms an important factor :—

manganese-ore
bauxite
magnesite
refractory minerals
natural abrasives
steatite
silica
gypsum
monumental granites
monazite
beryllium
corundum
cement materials

(iii) Minerals in which India may be considered self-sustaining for present needs and those of the immediate future :—

coal
aluminium-ore
gold
chrome-ore
building stones
marble
slate
industrial clays
limestone and dolomite
mineral pigments
sodium salts and alkalies
alum
glass sand
pyrites
borax
felspars
nitrates
phosphates
zircon
arsenic
antimony
barytes
precious and semi-precious stones
rare earths

(iv) Minerals for which India has to depend largely or entirely on foreign imports :—

copper-ore
silver
nickel
petroleum
sulphur
lead
zinc
tin
mercury
tungsten
molybdenum
platinum
graphite
asphalt
potash
fluorides

Minerals for controlled export and exchange

Those minerals which occur in very large deposits and which we can export (under control) over a fairly long period are :—

Iron ore (best exported as iron and steel products and not as raw ore) ;

mica (best exported as micanite or standard shapes consumed by the electrical industry)
magnesite (*rather doubtfully surplus* ; may be exported as magnesite bricks and chemicals)
manganese ore (*rather doubtfully surplus* ; may be exported as ferro-manganese or manganese salts)
ilmenite (best exported as titanium white and as paints)
cement materials (as cement and lime)
building stones (monumental granites and marbles)

Several minerals are now exported in a raw state or only partially processed because of the lack of home industries to consume them. In most cases India is actually importing products made out of these minerals. They may be considered, taking a fairly long view of developments here, to be just enough for our needs and therefore not available for export, *unless we can get something equally valuable in return, from the importing countries.* These are :—

ilmenite	chromite	monazite
barytes	rutile	zircon
bauxite	beryl	gold

Industries based on these must be encouraged and established in India, and any exports will have to be very carefully regulated—if exports are allowed at all.

With rapid industrialization, India may be in a position to export certain metals and mineral products other than those mentioned above—aluminium, magnesium and their alloys ; refractory bricks, chinaware, stoneware and other clay products ; glassware and some paints. Our surplus minerals—or rather manufactures from them—may be made use of for exchange with minerals or mineral products in which our resources are insufficient or very poor. These last include the following :—

SUGGESTED BARTER OR EXCHANGES

country	mineral products
United Kingdom . .	Nickel, copper, platinum and asbestos (of which she holds world control through her Dominions, principally Canada) and Malayan tin ;
France . . .	potash and phosphates (Morocco) ;
Belgium . . .	copper and industrial diamonds (Congo), cobalt and uranium ore ;
Germany . . .	potash ;
U.S.A. . . .	petroleum products, fluorite, sulphur, phosphates, zinc, copper, silver, molybdenum and alloy-steels (mainly in return for the large shipments of mica, manganese-ore and ilmenite) ;
Japan . . .	copper, sulphur, fluorite (Korea) ;
Ceylon . . .	graphite (in exchange for coal).

The most important deficiencies, amongst those mentioned, are the precious metals—platinum, etc., and silver ; the base metals—copper, lead, zinc and tin ; the ferrous alloy metals—nickel, molybdenum and tungsten ; and the non-metallics—sulphur, graphite and fluorspar. These have to be made good by imports from Empire countries and others. Those, except mercury, molybdenum, petroleum, sulphur and fluorite are available in sufficient quantities from Empire countries. Equitable agreements with Empire countries and with foreign countries, where necessary, could bring about an equilibrium in mineral economics, so that no country of any importance need suffer as a result of deficient mineral resources.

DETAILED GEOLOGICAL MAPPING AND NEW ZEALAND MINERAL RESOURCES

By E. O. Macpherson
(N.Z. Geological Survey)

A review of progress in geological mapping since 1860 shows that detailed mapping has led to some mineral discoveries, but particularly to a more realistic picture of the Dominion's mineral resources ; probably geological mapping has been more successfully used to indicate extensions of known metallic and non-metallic mineral deposits. A valuable discussion that touched on this general problem, mainly as it applies to the Crown Colonies, was contributed by a joint meeting of the Geological Society of London and the Institute of Mining and Metallurgy in 1943 (Contributions of Geological Surveys to Colonial Development ; *Bull. Inst. Mining and Metallurgy*, **464**, 1–11). The problems discussed at this meeting mainly apply to later decadence in colonial geological surveys, but most of the problems and difficulties there discussed have very direct application to this country.

GEOLOGICAL MAPPING IN NEW ZEALAND *

F. von Hockstetter and J. von Haast made the first geological map of New Zealand in 1860, and following from Hockstetter's visit to this country, several provincial governments established geological surveys and employed pioneer geologists.

The N.Z. Geological Survey was initiated in 1865, Dr J. Hector was first Director, and much of the geological work done by provincial surveys was incorporated in maps published by the N.Z. Geological Survey in 1869 and 1873 (approximately scales of 1/2,300,000 and 1/2,000,000). Many geological sketch maps were published by the Survey during the period 1865–1894, varying greatly in scale, detail and accuracy ; few topographical maps were then available, and the country was covered by forests. In 1893 Alexander McKay made many maps to demonstrate his excellent reports, these were published mainly by the Mines Department.

By 1905 the results of the pioneer reconnaissance surveys were published on the various maps noted above ; and in that year Dr J. M. Bell was appointed Director of the N.Z. Geological Survey as successor to Sir James Hector. Bell introduced systematic geological mapping, including topographic mapping, his objective being to produce a detailed regional map of New Zealand. This scheme was carried further by the next Director, Mr P. G. Morgan, until 1927, and from that year till 1939 by Dr J. Henderson, when systematic regional mapping almost ceased entirely owing mainly to war demands for special mineral surveys. As noted above,

* Morgan, P. G. 1921. The Status of Areal Geological Mapping in New Zealand. *N.Z. J. Sci. Tech.*, **4**, no. 5, 254-256.

Bell introduced topographic mapping in conjunction with geological work, but his successors dispensed with topographers, either owing to reduced departmental funds or their own views on economy; this was retrogressive for both topography and geology were affected and the field geologists' work was greatly increased.

The total area of New Zealand is roughly 103,000 sq. miles, about 25,000 sq. miles have been mapped and maps are published on a scale of 1 in. = 1 mile; 7,086 sq. miles are mapped, or in progress, but unpublished, leaving approximately 65,700 sq. miles unmapped except by rough reconnaissance. Special detail maps of gold mining, coal mining and prospective oil and gas bearing regions have also been made. Hence about one-third of this country has been mapped, on what now would be considered fair reconnaissance class, and two-thirds remains to be mapped even in such detail. There is a considerable accumulation of unpublished work (7,086 sq. miles); this becomes a disability for much of it is now obsolete owing to changing geological concepts. These remarks will not be regarded as adverse criticism for no geological map can be regarded as complete, but merely records of progress of geological theory; it is now recognized that geological maps, especially those of regional surveys, must be published in a generation or they become out of date.

It is not necessary here to discuss critically the published maps of the N.Z. Geological Survey; they compare favourably with Colonies and Dominions in a similar period of development and are interesting in that they express structural and stratigraphical ideas of the several geologists who made them; but many of the views are now untenable. Spatial relations and contacts of the various rock stratigraphic units in many regions mapped show a peculiar unrelatedness, owing mainly to wide projection of formation boundaries and lack of faunal controls.

In 1925 oil exploration commenced in this country, plane-table mapping was introduced, also microfaunal studies and later in 1938–1942 reflection, seismic and gravity meter surveys; extensive regions of three main sedimentary basins were remapped. Although this work did not result in oil discoveries, New Zealand greatly gained in geological information and fresh viewpoint.

It is necessary to indicate the unavoidable defects in the published 1 in. = 1 mile geological map noted above, for on the geological evidence conveyed by them we must decide the answer required from this discussion; 'will mapping in greater detail, using a larger scale, aid in increasing the mineral resources of this country?'

INTENSIVE GEOLOGICAL MAPPING AND MINERAL RESOURCES

The status of geological mapping has been roughly outlined and it now remains to answer the question whether extensive geological study and mapping is a worth-while approach to mineral discoveries: the answer to this question is in the affirmative; probably not from the direct angle of new discoveries, but as a way of approach to such discoveries and also from the viewpoint of a more accurate stocktaking of our mineral resources.

Of the metals, New Zealand has considerable variety, but years of

prospecting appear to indicate that the majority of metals are present in non-commercial quantities ; gold, silver, iron ore (limonite and titano-magnetite), manganese, antimony, lead, zinc, chromium, copper, tungsten (scheelite) and various other metals in smaller amounts ; of the metals, gold (lode and alluvial) has been far the most important.

Among non-metallic deposits coal is the most important, but this country has large reserves of limestone and marble, clay, bentonite, magnesite, dolomite, medium- and low-grade phosphate, pumice, peat, serpentine, talc, glass-sand, and smaller deposits of barite and fluorite, asbestos, diatomite, fuller's earth, oil shale and glauconite. It is probable that workable gasfields will be discovered, but less probable that substantial oil pools occur. The metallic and non-metallic deposits enumerated above are too numerous for extended discussion of each, but I will endeavour to develop arguments for intensive geological mapping by discussing gold, coal and prospective gas and oil bearing deposits ; the arguments used will in the main apply to most other deposits. Gold and coal are far the most important metal and non-metal deposits developed in this country and a brief note on oil prospecting will illustrate how intensive geological study and geophysical work can reveal far-reaching new views on stratigraphy and regional structure.

Gold—Alluvial gold is found mainly in the South Island and more especially in the neighbourhood of outcrops of Palaeozoic rocks. From the late Cretaceous-Early Tertiary, also Pliocene and Recent gravels of Otago, Westland and Nelson, large quantities of gold have been won ; alluvial gold is rare in the North Island. At Preservation Inlet (south-west Otago), and in the North Westland, Reefton and Nelson districts, gold-bearing quartz lodes, cut argillites, greywackes and sub-schists of lower Ordovician and upper Silurian age are found. The Otago schist and Palaeozoic age rocks contain gold and other mineral lodes and have produced a modest amount. The Hauraki region is the gold mining district of the North Island, here the lodes are emplaced in middle to late Tertiary andesites and, less frequently, in rhyolites. This Dominion has produced approximately £110,000,000 of gold since the 'sixties' and the three regions, Otago, West Coast Nelson and Hauraki have contributed about one-third each.

The three main goldfields were mapped in the detail considered adequate for the time, by the geologists who studied them. They applied the structural views and theories of ore deposition of their day, and it is a debatable question whether more detailed mapping followed by geophysical surveys and core-drilling of selected areas would reveal new ore-bodies or extensions of known ones, and in this country two schools of thought emerge, neither able to convince the other by argument. One school holds that, notwithstanding extensive prospecting, both for lodes and alluvial deposits through the years, no important discoveries have been made. The other school contends that the ore-bearing regions have as yet not been studied exhaustively, that the fields were mapped twenty to thirty years ago, and those that studied them were limited by the views and methods of their times. For example, the important modern ideas on structural control of ore-bodies had not then emerged and geophysical methods and modern core-drilling technique were not available. It is

almost certain that the first view is correct, but probably not owing to real evidence, merely the hazard of gold mining, and it is always safe to forecast that gold prospecting ventures will fail. Until more evidence is available hope will still persist.

Some factors that support the view that past geological study was not adequate are (*a*) changing geological concepts, such as later views on structural control, (*b*) later theories on ore deposition and spaced periods of ore emplacements, (*c*) disruption of ore-bodies by faults of compression type, formerly regarded as normal or tension faults, (*d*) shearing out of ore-bodies downward through low angle shears. Present or potential advances in geophysical methods and possibly improvements in ore-dressing methods may also change present views regarding economy of ore-bodies.

There are many abandoned gold and some other metal mines in this country, and it seems reasonable that intensive re-study along modern lines, of selected ore districts may reveal profitable mines ; in support of this line of argument, some lode districts that were re-studied during the depression years showed important structural control of valuable ore-bodies which was not realized before. If these structural relations (the lodes were emplaced along sheared synclinal axes) had been realized when these profitable mines were being exploited, geologists could have provided valuable guides to aid the mining industry. From this example it seems probable that other lode regions are worth re-study, when we realize that during the time they were geologically studied and mined the structural view of tension dominated geological thought.

The above remarks apply mainly to lodes in the Palaeozoic rocks of the South Island, but similar arguments can be deduced for and against the current theories on the Tertiary andesite fields of Hauraki ; for example, later views on structural control can be applied to that region also and these views, in conjunction with the hypothesis of older mineralized andesites, with considerable topographic relief, overwhelmed by younger rhyolites, prompt the view that the Hauraki region should be geologically re-studied before being finally abandoned.

In the alluvial fields, of late years prospecting and dredging has contributed wealth to this country ; dredging, at one time a thriving industry, came to a standstill and all gold bearing alluvial ground was regarded as exhausted, the written records reveal this viewpoint. However, deeper alluvial ground is now being vigorously worked, at a fair return, by giant dredges, and this revival is not solely owing to the increased price of gold, but mainly to more effective mechanical equipment being provided to dredge deeper ground.

A further example where later geological study has increased the prospective value of alluvial deposits, can be taken from the quartz conglomerate bankets, preserved in the synclinal valleys of Otago Central. These late Cretaceous-Early Tertiary deposits undoubtedly contain reserves of fine-grained alluvial gold, but mining methods are not yet devised to work them. It is suggested that a gravity meter survey of these synclinal basins may reveal areas of high basement rock where ' buried hills ' of schist approach near enough to the surface to permit the quartz banket to be prospected and mined.

Several ' buried hills ' of this type were discovered and vigorously worked

by the pioneer miners ; these deposits were first exploited by shallow workings, later as sluicing claims, still later with hydraulic elevators and the deposits were generally abandoned when the dip of the banket, down the flank of the ' buried hill,' took the gold to depths beyond the capacity of mining methods then in use.

Coal—The coalfields of this country were mapped many years ago, the task being undertaken as part of the regional survey and the detail and map control were considered adequate for those times ; estimates of coal reserves were computed from the map data. In later years the need was felt for more accurate estimates of coal reserves, and the Coal Survey section of the Geological Survey was organized to re-map the coalfields ; this work is now in progress. So far the mapping in greater detail has shown that previous estimates of coal reserves were not reliable, in some fields the reserves have been much reduced, other fields have shown increased reserves. Certainly a more accurate picture of our coal reserves has emerged, and structural detail such as faults, folds, thickness of over-burden, will greatly assist mining engineers to prospect more economically and exploit the reserves available. Opencast mining was introduced during the war years and the Coal Survey section has given valuable advice on substantial reserves that can be mined by this method.

Oil exploration—During 1924–1930 and 1937–1944 extensive oil explorations were done in this country, the standard practices of British and U.S.A. oil companies were applied, reconnaissance surveys to outline the broad structural areas, followed by detailed plane-table mapping of selected structural areas and close study of late Cretaceous and Tertiary foraminifera. In 1939–1943 extensive regions in the three main sedimentary basins were studied by geophysical methods (reflection seismic and gravity meter). This exploratory play resulted in many dry holes, but from it emerged important data on the stratigraphy and diastrophic history of this country. Detailed geological mapping showed many overlaps and discordances around the crestal parts of the structures, and in the adjacent synclines the sections were abnormally thick, and stratigraphic breaks, reasonably persistent on the crestal areas, were absent or indefinite in these synclines. From these relations it seems evident that the domes and anticlines have grown by recurrent orogenesis and have not a simple orogenic history as has previously been supposed. Details discussed cannot be attempted here, but the point is emphasized that detailed mapping, microfaunal studies, gravity meter observations followed by drilling, revealed an entirely different structural picture from that inferred prior to drilling. It is not a remote possibility that the disappointing drilling results may lead to further oil explorations and point the way to oil and gasfields in stratigraphic and overlap traps on the flanks of some of these structures.

Geophysical surveys—Prospecting guided by these methods has had startling successes and failures, like prospecting directed on purely geological deductions, but from some experience with geophysical methods, the writer realizes that maximum chances of success are usually provided when the preceding geological work is thorough and geological deductions well founded. The future will see a wider application of these methods in search for new ore-bodies and a development for this purpose similar to their present application for oil prospecting. I do not know of any

startling new developments in geophysical prospecting and surmise that advances will come by improvement and adjustment of proven methods, interpretation technique, and closer co-operation with geology. This implies that geologists must be well informed on the problems to be jointly attacked, which further emphasizes that more intensive structural studies will be required of them in the future. Before geologists can criticize constructively geophysical results, they must be reasonably sure that their fundamental concepts are well founded.

The three examples cited—gold, coal and oil prospecting—show how more detailed studies of regions previously mapped have altered established geological views and increased mineral resources or provided a way of approach to new discoveries. Phosphate, bentonite, and magnetite deposits have also been discovered in recent years by re-study, and detailed mapping and estimates of iron ore reserves have been greatly reduced by re-study and prospecting. Increased detail, using larger scale maps will certainly be applied in the future and the hope is justified that ore-bodies and other mineral deposits will be discovered.

New Zealand is beginning to study its thermal regions with a view to using them.

THE MINERAL RESOURCES OF THE UNION OF SOUTH AFRICA

By Dr Louis T. Nel, F.G.S.

INTRODUCTION

The mineral resources of the Union of South Africa have been the subject of numerous published reports and pronouncements in public during recent years and it is hardly necessary here to cover the same ground in detail. It may however be useful in assessing the economic and industrial potentialities of the British Empire to know what is locked up in the land and to mention what steps have been taken by the South African Government to extend its knowledge of the country's latent resources.

Statements to the effect that South Africa is exceptionally rich in mineral deposits and has vast or inexhaustible mineral wealth should be accepted with reserve. It is true that widespread occurrences of most minerals have been recorded but many of them are not sizable or rich enough to be of any economic significance. Of some minerals South Africa undoubtedly has large reserves ; of others she has little left over for export after fulfilling local needs ; and it is not unusual to import certain mineral substances not economically producible in this country.

The Government is bent on fostering secondary industries, the underlying idea being that truly stable industrial development is based on the utilization of the country's own resources. To promote such industrial expansion a comprehensive survey of all mineral and other resources has been decided upon and particular attention will be paid to minerals that can easily be processed and fitted into the industrial structure now taking shape.

The Union of South Africa and South-West Africa together embrace an area of approximately 795,400 square miles. Much of this large territory has not been geologically examined in detail. Large tracts have not even been covered by reconnaissance geological survey.

MINERAL PRODUCTS OF THE UNION

Particulars of the mineral occurrences and notes on their exploitation are contained in the reports listed at the end of this paper. A brief survey of the mineral industry of the Union of South Africa given by Dr S. H. Haughton, Director of the Geological Survey, to the American Institute of Mining and Metallurgical Engineers * in November 1945 is also appended.

As is well known, gold is the major product of South Africa, constituting as it does more than three-quarters of the total value of the Union's annual mineral output. This total value was £122,500,000 in 1944 and £127,150,000 in 1945. The two next most important mineral products are diamonds and coal, which in 1938 accounted for 10·5 per cent and 5·4

* This survey still awaits publication in the U.S.A.

per cent and in 1939 for 2·36 per cent and 4·36 per cent respectively of the total value of the country's mineral production. The estimated value of diamonds recovered in South Africa in 1939 was approximately £2¼ million, while in 1945 it reached £6,425,000. Naturally, full attention will be devoted to the maintenance and further development of output of these three products which are vital in the Union's economy. Gold developments in the Orange Free State and Western Transvaal and the reopening of the Premier and Jagersfontein mines (particularly for the production of high-class industrial diamonds) are evidence of this. Of iron, chrome ore, manganese, asbestos, vermiculite and corundum the reserves are large enough to provide for increased output extending over long periods if the need should arise.

The following production tables, compiled in the office of the Government Mining Engineer and taken from the Official Year Book of the Union of South Africa for the year 1941, give some idea of the relative importance of the various minerals produced in the country. The figures are indicative of the normal pre-war output and do not show the additional production of certain material caused by the war.

South Africa's resources of chrome ore are probably the largest in the world, and undoubtedly constitute an asset of great potential value. Stratiform deposits dipping at low angles have been traced over approximately 73 miles along strike in the Lydenburg district and 128 miles in the Rustenburg district. The ore is mainly low to medium grade, the average being probably below 40 per cent Cr_2O_3, with oxides of iron, aluminium and magnesium ranging roughly between 23 and 27 per cent, 12 and 20 per cent and 9 and 12 per cent respectively ; it is characterized by low silica, lime and phosphoric pentoxide. Certain bands yield an ore of 48 per cent Cr_2O_3. In the two districts mentioned (both in the Transvaal) magnetic iron ore which contains titanium has the same mode of occurrence and the available reserves are of similar proportions to those of the chrome ore. This type iron ore, which is quite distinct from the ores at present used in the expanding iron and steel industry, is practically pure except for titanium, the content of which varies from 8 to 24 per cent—an undesirable element from the current metallurgical point of view ; vanadium pentoxide varies from a trace to 1·5 per cent. Considerable quantities of manganese ore occur near Postmasburg in the Northern Cape Province. The bulk of the ore is low grade owing to its iron content. The ore ranges from a high-grade manganese ore to manganiferous iron ore ; other impurities occur in insignificant quantities, except in a few places where silica may exceed the penalty limit of 8 per cent.

Under standard metallurgical practice these large reserves of chromium, iron and manganese, with titanium and vanadium as possible by-products in the case of the magnetic iron ore, are not fully exploited, or are left practically untouched. A beginning has been made in the use of 44 per cent chrome ore in the manufacture of stainless steel. The question arises as to whether at this stage new processes should not be evolved, or existing processes adapted to treat such low-grade ores in order to make the base metals available to industry at reasonable prices, or whether they should be left for future exploitation when the types of ore used in present metallurgical processes approach exhaustion. The magnitude of the reserves

(a) Quantity

CLASSIFICATION		1936	1937	1938	1939	1940
Asbestos	ton	25,237	28,069	22,282	23,220	23,170
Bismuth	lb.	—	526	7,498	4,686	860
Chrome Ore	ton	107,198	186,379	128,899	184,006	117,279
Coal sold	,,	15,996,376	16,718,234	17,536,230	18,166,399	18,934,005
Copper	,,	12,196	13,920	14,683	16,378	18,766
Corundum	,,	4,851	2,466	1,540	2,625	4,211
Diamonds	met. car.	623,923	1,030,434	1,238,608	1,249,828	543,463
Fluorspar	ton	2,674	3,348	5,207	10,724	6,995
Gold	fine oz.	11,336,214	11,734,575	12,161,392	12,821,507	14,046,502
Graphite	ton	65	69	59	65	86
Gypsus	,,	35,232	36,582	42,824	44,955	50,929
Iron ore	,,	401,565	509,046	557,015	539,589	693,093
Iron pyrites	,,	27,043	31,873	34,191	32,877	40,456
Kaolin	,,	385	462	628	888	2,262
Kieselguhr	,,	107	166	171	271	735
Lead	,,	9	96	78	62	40
Lime and Limestone	,,	1,655,104	2,059,393	2,157,573	2,379,207	2,209,196
Magnesite	,,	1,910	1,829	2,660	4,215	8,764
Manganese ore	,,	236,861	557,210	422,757	388,154	313,220
Mica	,,	378	1,529	907	1,244	950
Mineral fertilizers (Agricultural lime)	,,	10,605	8,989	15,635	20,9c	22,986
Mineral paints	,,	6,848	5,834	6,002	7,033	9,080
Nickel	,,	—	—	49	439	459
Osmiridium	fine oz.	5,371	5,667	5,884	6,076	6,435
Platinum	oz.	29,045	30,125	38,862	47,912	52,082
Silver	fine oz.	1,075,625	1,100,641	1,135,374	1,182,516	1,292,284
Soda	ton	2,264	2,319	2,275	2,525	2,785
Talc	,,	412	296	377	392	1,842
Tantalite	lb.	13,612	1,604	670	1,298	440
Tin	ton	1,065	955	1,156	809	1,012
Tungsten ores	,,	21	36	111	63	113

(b) Value

	1936	1937	1938	1939	1940
	£	£	£	£	£
Asbestos	337,229	430,761	424,078	523,198	497,061
Beryl (Emerald) Crystals	6,120*	10,838	8,601	3,527	—
Bismuth	—	40	707	560	161
Chrome ore	182,909	344,037	239,888	347,604	217,644
Coal sold	3,949,736	4,205,836	4,729,423	4,823,886	5,325,932
Copper	385,571	610,192	464,466	537,306	629,296
Corundum	38,240	18,817	12,454	18,355	35,610
Diamonds	2,125,216	3,444,678	3,496,243	2,604,172	1,620,467
Fluorspar	4,108	6,230	12,705	24,822	17,309
Gold †	48,153,177	49,845,304	51,658,311	54,462,300	59,665,749
Graphite	1,858	1,932	1,697	1,814	2,436
Gypsum	28,161	30,780	37,024	38,424	45,010
Iron ore	94,129	118,559	134,551	120,419	275,776
Iron pyrites	28,456	32,707	39,194	36,930	48,108
Kaolin	448	533	858	1,099	3,145
Kieselguhr	171	266	279	626	1,332
Lead	54	831	865	705	377
Lime and Limestone	733,280	790,922	802,663	828,629	848,751
Magnesite	3,885	3,692	5,449	8,567	18,900

Values are expressed in Union currency.

* Includes beryl (non-precious) to the value of £38.

† At standard value of £4.24773 per fine oz. The silver and osmiridium and much of the ron pyrites shown in the above table are by-products of the gold mining industry.

cheap labour, relatively cheap power and mining or quarrying are some of the factors which would seem to justify long-term planning for large-scale production. Increasingly wider uses, for example, could conceivably be found for chromium if production on a large scale makes it possible for the metal to be sold at a lower price.

Coal reserves in South Africa are large. During the war the country became one of the world's foremost coal exporters but the total output is

Value of Raw and Semi-raw Base Metals and Industrial Minerals imported in 1938 and 1939

Base metals

	1938	1939
	£	£
Aluminium	82,193	67,979
Brass and bronze	59,611	60,467
Copper	159,277	144,008
Composition metal	53,345	71,278
Ferro-alloys	38,964	60,922
Galvanized flat and corrugated sheet	553,157	657,906
Iron and steel *	963,177	683,578
Plates (tin, lead, zinc or otherwise coated)	408,051	520,698
Lead	67,233	70,112
Mercury	8,320	17,949
Tin	93,549	155,447
Zinc	101,948	141,863

Industrial minerals

	£	£
Crude oil and derivatives	3,841,461	4,873,927
Asphalt and bitumen	97,421	97,230
Gypsum	11,011	10,228
Nitrate of soda		86,730
Phosphates (rock-, super-, basic slag)	347,388	358,357
Pigments (dry)	112,697	143,142
Precious stones (not cut or polished)	75,635	50,475
Sulphur (rock and flowers in bulk)	99,213	78,744

small compared to what could be produced should industry require more coal. Hitherto much wealth has been thrown away by wasteful mining and a neglect of the by-products. Through selective mining poorer grades of coal useful for generating electric power at low cost, for producing oil and for providing the raw material for the manufacture of plastics and the many synthetic products that have their origin in coal, have been left in mines or cast on the dumps and are lost to future exploitation. Good coal is still being picked out and the lower-grade portions of thick seams sacrificed for immediate profits. The known reserves of coal capable of producing metallurgical coke by the usual methods are inadequate for the future requirements of South Africa's expanding industries, particularly the iron and steel industry. New undeveloped fields, however, are being explored for coking coal, and the possibilities of low-temperature carbonization for

* A large expansion of the South African iron and steel industry is being planned to meet an increasing demand from industrial development in the country. A new iron and steel works is now being set up for a production of one million tons of steel per annum, which is twice the capacity of the steel works at Pretoria. In South Africa the average price of locally produced steel is now actually lower than the price of American steel in America and British steel in Great Britain.

producing coke are being examined. Experiments are also being conducted in testing mixtures of non-coking and coking coal from different seams : the results are promising. The Government is appointing a Commission to inquire into the methods of mining coal in South Africa with special reference to the conservation of coking coal.

Deposits of low-grade mercury ore (cinnebar), discovered in 1936 in the Murchison range, north-eastern Transvaal, were not worked until 1940. During 1942, 573½ flasks were produced and by the end of 1943 the annual production had risen to over 1,000 flasks, an output more than sufficient to supply all present requirements of the Union.

Vermiculite deposits, of considerable size, were recently discovered in the Lowveld (Transvaal). The usefulness of this mineral particularly for insulation purposes is not yet fully appreciated in the Union and its incorporation in the manufacture of industrial or building materials has not got beyond the experimental stage. Good progress has been made in exfoliation processes mainly due to the research conducted by the Government Metallurgical Laboratory in Johannesburg.

Certain mineral raw products and semi-raw base metals have to be imported to meet local needs. Either payable deposits have not been found or outputs are inadequate. The values of the most important imports, i.e. those above £10,000 in value, are shown in the above table compiled from figures given in the 'Annual Statement of the Trade and Shipping of the Union of South Africa' compiled by the Department of Customs and Excise. The imports for 1938 and 1939 are given as being indicative of the normal trade.

ORGANIZATIONS TO ASSIST THE DEVELOPMENT OF THE MINERAL RESOURCES IN SOUTH AFRICA

The Government has established the following organizations to investigate South Africa's mineral resources and to assist in their development :

(1) The Geological Survey, which is responsible for the geological map of the Union and South-West Africa, and for the investigation of the mineral resources.

(2) A mineral development section of the Government Mining Engineer's branch of the Department of Mines to collect information as to mineral occurrences and their economic exploitation, and also to deal with all inquiries in respect of supply of, demand for, and marketing of base minerals locally and overseas. In order to maintain closer contact with the requirements of overseas markets a technical officer, known as the Overseas Representative, Mines Department, is permanently stationed in London. The mineral development section also renders direct financial and technical assistance to small mining concerns.

(3) The Government Metallurgical Laboratory, which handles all problems submitted to it in connexion with the treatment and processing of ores and the preparation of products for marketing and their application to use in local and overseas industries.

(4) The Fuel Research Institute, whose main function is to undertake research in solid, liquid and gaseous fuels, and to investigate fuel resources.

INTENSIFICATION OF MINERAL EXPLORATION IN SOUTH AFRICA

The need of reliable information concerning mineral resources and of knowing where essential minerals could be raised at short notice seems to be fully realized only when a state of national emergency develops. At other times it is usually difficult to persuade the powers that be to grant facilities and to provide funds for comprehensive and systematic vestiga - tions snto the location of minerals, their extent and quality, and the degree and manner in which they should be utilized or conserved.

The outbreak of war, for example, created an urgent and unprecedented demand for mineral raw products both for the manufacture of war materials and to meet the demands of local industries whose channels of supply had been reduced or cut off. Increase the output from known deposits and find and open up new ones as quickly as possible, is a familiar cry in times of stress. The speed and effectiveness with which it is possible to meet such a pressing demand depend largely upon what has previously been accomplished in the way of long-term planning and systematic surveys of the country's mineral resources.

The Government institutions responsible for the investigation of South Africa's mineral resources were mentioned above. The onset of war, however, created demands for increased deliveries of certain minerals and the necessity of finding new sources of supply of others. In order to intensify the search for ores the following measures were taken :

(a) The Base Mineral Amendment Act of 1942 and the Natural Oil Act of 1942 were passed by Parliament. The former is designed to facilitate the development of base minerals on private land and to prevent unwarranted locking-up of these minerals. It also makes provision for the State to investigate the occurrence or possible occurrence of any base mineral, and for the establishment, with the sanction of Parliament, of a State mine to work base minerals.

Under the Natural Oil Act, designed to ensure rational exploitation in the event of a discovery of natural oil, the right to prospect and mine for natural oil is vested in the State, but the right may be given out under lease to an applicant subject to certain provisions.

(b) The mineral development section of the Government Mining Engineer's establishment was authorized to undertake State prospecting.

(c) The establishment of the Geological Survey was appreciably increased.

These measures have made it possible for the State to assist in finding and developing sufficient ore for increased outputs and also to maintain reserves, thereby assisting the Government's policy of promoting industrial expansion.

During the war the Geological Survey was concerned mainly with the search for minerals likely to be of value for the war effort or to meet the requirements of local industries. Extensive and detailed geological mapping and investigations were undertaken of large, potential mineral-bearing areas, such as Namaqualand, which gave a clearer picture of their economic possibilities. A better knowledge of the mode of occurrence and distribution of ores such as, for example, those of tungsten and tin was obtained. For

these and other investigations in connexion with South Africa's resources of fuels the use of aerial photographs, specially taken for the Geological Survey, proved of great value. State prospecting by the mineral development section was initiated and broadened.

It has not yet been possible to publish much of the mass of information on geological structure and mineral resources collected as a result of these activities. It will, however, be made available to the public in due course, through the medium of the official publications of the Department of Mines. Some of the reports are already in the press ; others are nearly ready for printing. Among them are the following : ' The geology of the Messina copper mines ' ; ' Diatomaceous deposits with special reference to kieselguhr ' ; ' Geochemical survey of underground water supplies of the Union ' ; ' The manganese deposits of the Union of South Africa ' ; ' The vanadium deposits in the Otavi mountain land, South-West Africa ' ; ' The phosphate deposits of the Union of South Africa ' ; ' The Thabazimbi iron deposits ' ; ' Some glass sands near Pretoria.' Further, the results of the survey of several mineralized areas, for example, Nelspruit, Leydsdorp, Messina, Schweizer Reneke, Postmasburg, the Transvaal tin fields, Namaqualand, and of investigations into the coal resources and the possibility of finding oil, will be presented in the form of geological sheets with explanations, memoirs or bulletins.

Geological work and mineral exploration on the scale followed by the State during the war are to continue. The importance of knowing what we have in the way of mineral resources and of conserving them is now realized. To carry out this work efficiently and to meet the demands of Government departments and of the public for assistance in geological problems connected with underground water, foundation sites, the supply of building materials and like matters, the Geological Survey with eighty-nine professional and technical posts on the present establishment has been organized into the following branches, each with a principal professional officer in charge :

The branch of Regional Geology, which is responsible for the production of geological maps, particularly the standard geological sheets.

Mineral Deposits branch, which attends to mineral exploration and economic aspects of geology, exclusive of fuels and water.

The Fuels branch for the investigation of the geology and economic aspects of coal and oil.

The branch of Underground Water Resources and Geophysics for the survey of underground water resources, the selection of borehole sites and the application of geophysical methods of prospecting.

The Mineralogical Laboratory, where mineralogical research is carried out and minerals and rocks are identified, including free identifications for the public.

Another two branches are those of Information and Office Administration respectively.

THE NECESSITY FOR SCIENTIFIC METHODS OF MINERAL PRODUCTION

Most of the obvious mineral deposits have already been discovered. New discoveries in recent years have greatly fallen off in number notwithstanding the mounting demands of modern industry, demands which were greatly augmented by those of the war. The necessity for increasing the rate of discovery of new deposits of ore and fuel, of finding extensions of known ore bodies and of conserving reserves has become a matter of special concern. To achieve these objects and to provide adequately as far as possible for future industry, scientific methods of mineral exploration will have to be adopted or more widely applied than has been the case hitherto.

Scepticism as regards the effectiveness of geological methods of finding ore is still evident in some quarters. There is a lingering reluctance to admit that new deposits might be found by methods other than those followed in the past, methods which left too much to chance. Although occasional chance discoveries are still likely to happen, there is really very little left on the surface that has escaped the sharp eye of the old type of prospector.

The production of geological maps—the more detailed the better—the application of geological knowledge and methods, with aerial surveys, geophysical prospecting and other new techniques based upon scientific principles, as auxiliary tools, offer the best means of finding new ore bodies, especially where they are concealed.

The geological map is fundamental to any systematic and efficient search for new mineral deposits ; further, much can be gleaned from it that is useful for industrial development and for civil engineering schemes. From the interpretation of a geological map it is usually possible, in the first instance, to delineate areas in which the prospects of finding minerals or raw materials of economic importance are better than those of others. Subsequently, more detailed geological mapping of the promising areas provides the additional data necessary for successful detection of ore bodies and their development and exploitation.

Government geologists have used aerial photographs successfully over wide areas for mineral exploration, particularly over stretches in respect of which there are no dependable topographical maps. The quickest and most accurate results in geological mapping are obtained by the use of air photography with topographical maps prepared from the photographs. Particularly useful in mountainous, arid and sparsely populated regions, aerial photographs have proved to be a boon to the field geologist by revealing to him outcrops and structures he might otherwise have missed, by enabling him quickly and accurately to locate his position in the field, and by providing him with an excellent base upon which to record his field observations in great detail if necessary, and by reducing considerably the time spent in carrying out an effective survey of the area allocated to him. Such a saving of time is particularly striking in reconnaissance surveys of large regions.

Geophysics, which helps the geologist in the study of sub-surface geological conditions of structure and material, has been actively applied by geologists

and geophysicists in South Africa in prospecting for subterranean ore deposits or in the location of underground water. Magnetic, electrical and gravimetric methods are those which have been mainly adopted, but the practical application of seismic reflexion and other principles is also under consideration. The successes obtained so far appreciably outweigh the failures, and in this connexion might be mentioned the extension of the Witwatersrand goldfields westwards, the discovery of another goldfield around Odendaalsrust in the Orange Free State, and the high proportion of successful boreholes for underground water selected in difficult ground as compared with those obtained by other rather haphazard methods which include the use of the divining rod but not the application of any geological knowledge.

Geophysical deductions have on occasion been misleading but this can mostly be attributed to a lack of sufficient geological knowledge of the ground that had to be explored. The more complete such information is the more accurate will be the interpretation by a qualified person of the anomalies furnished by the geophysical instruments and hence the better the chances of success.

The desirability of carrying out regional geophysical surveys in South Africa and other territories of the Commonwealth, where little or nothing has been done in such regional work, might be considered. The information provided by such surveys would be of great value for geological investigations and would also be utilized to great advantage in other spheres of scientific investigation. Geophysical maps compiled from these surveys are useful in proportion to the detail they show.

Some of the geophysical reports in the course of preparation for publication by the Geological Survey will deal with gravimetric surveys in the Southern Karroo and Orange Free State, specific gravity determinations of South African rock types for gravimetric survey purposes, and the application of resistivity methods in South Africa.

A branch of geophysical science to which some attention has also been devoted in South Africa is that connected with the measurement of temperatures in deep boreholes and the determination of thermal conductivities of core samples. The advisability of continuing and extending observations of this type over a wider field might be considered. The value of the information derived from these investigations is primarily scientific but its importance in problems of deep mining is evident and there may be unsuspected practical applications. The keeping of accurate records of earthquakes and other earth movements in so far as they have connexion with geological problems is also being devised.

Then there is the problem of the correlation of non-fossiliferous sediments. These sediments together with granites and other igneous rocks with which they have definite time relationships occupy vast areas of the African continent. Correlations have been based mainly on lithological characters and geological structure but these factors can be of doubtful value. The radium-lead ratios and the helium contents of igneous rocks have been examined for their possibilities as reliable age indicators but the results obtained appear to have been at variance with field evidence in some areas. Work of this nature should continue, however, especially as it is likely that recent advances in the knowledge and technique of radio-active

methods will eliminate serious discrepancies. Reliable results will not only be of interest from a purely scientific point of view but must have considerable bearing upon some of the problems of the economic development of the country's minerals.

COLLABORATION IN MINERAL RESEARCH

Geological and mineralogical organizations in the Commonwealth have a common interest. Some aspects of this have been referred to in the previous section of this paper ; others are likely to become apparent if more frequent and closer contacts could be established among investigators. Collaboration between the personnel of cognate organizations in tackling problems of mutual interest and co-operative research are bound to stimulate interest and increase the efficiency and value of the work performed by them. Opportunities would be afforded for an interchange of ideas and for comparing results, for planning and co-ordinating research in geological science of direct interest to two or more members of the Commonwealth, of assisting one another should difficulties be experienced, and for studying what has been achieved elsewhere in the field of mineral research and exploration.

Some organizations or scientists in the Commonwealth are more or less isolated from the larger centres of scientific and industrial research in the United Kingdom and elsewhere. They may suffer too from a lack of suitable equipment necessary for the prosecution of their investigations. Owing to great distances and travelling expenses, opportunities seldom occur of meeting eminent specialists and of drawing upon their extensive and varied knowledge. Government and university organizations usually experience difficulty in obtaining official sanction and assistance for selected scientists to travel abroad in order to make practical acquaintance with the latest geological and mining teaching, survey and research, and to obtain the necessary knowledge and experience for effective application in the survey of their country's mineral resources. Apart from a readiness to co-operate, collaboration in the survey of the mineral resources of the Commonwealth would seem to be dependent mainly on whether regular meetings of representatives are held at which problems under investigation could be discussed and research or survey programmes formulated and co-ordinated, and whether relevant information of the latest scientific advances and current technical developments can be widely and promptly disseminated.

Mutual assistance—The Geological Survey of the Union of South Africa is the oldest of the African geological surveys. It is also the largest and perhaps best equipped. The general attempt of geological surveys in southern Africa outside the Union has been to bring the facts discovered by them into conformity with the more highly co-ordinated facts in the Union. To collaborate with and assist the other geological organizations in the African continent, the Union survey could participate in any co-operative effort with the object of developing the mineral potentialities of the African territories. Such co-operation might include assistance in collating and co-ordinating geological data. Visiting geologists who wish to examine instructive exposures in South Africa could be assisted and

others could avail themselves of the facilities offered by the mineralogical laboratory for any mineralogical and petrological studies they might like to carry out during their visit. Opportunities might also be presented to study the technique and results of the various geophysical methods of prospecting for minerals and underground water which geologists of the Union Geological Survey have been actively applying over a period of several years. In fact, assistance has been rendered to visiting geologists on several occasions in the past, usually to the mutual benefit of both host and guest. Collaboration among the geologists in the African territories could be further promoted if arrangements could be made for periodic meetings to be held of directors or representatives of African geological surveys to ascertain the results of the latest surveys in different parts of the continent and for the purpose of discussion of common problems.

Where ore has been found, problems of extraction and dressing of the ores may be encountered. The Government Metallurgical Laboratory of the Department of Mines of the Union of South Africa might be prepared to assist British African territories with such difficulties, as it has already done in the past on special occasions.

The need of expert opinion and advice is felt sometimes in connexion with problems arising from investigations or the application of research methods that are either new or of a type that has not been undertaken before in the country concerned. For example, in South Africa the Geological Survey has been investigating the possibilities of finding natural oil. Information has been collected as a result of detailed geological and geophysical mapping in conjunction with diamond drilling. An experienced oil geologist from abroad to study all the evidence available and to advise local geologists whether additional investigation is justified and, if so, what should further be done to prosecute the search for oil as effectively as possible, would be of great advantage. Were there some system of collaboration or interchange of scientists in operation, the visit of such an authority to act as a consultant could probably be arranged without any difficulty. Further, before a specific piece of research or a new type of investigation is undertaken, it would be very desirable to select one or more geologists to proceed overseas with the object of studying what is being done there in that particular field of geological science, and of applying the knowledge so gained to the new project. Such a procedure would enable them to keep in touch with modern ideas and thus obviate the danger of applying methods which have become obsolete ; it would greatly improve the prospects of success of a new project.

Geology, probably more than in the case of any other science, has gained by contributions of competent geologists who were able to travel and take observations abroad. Rock exposures in some parts of the Commonwealth may furnish the clues to problems of interpretation of local geology where the evidence is imperfectly exposed. Might it not be possible to arrive at some arrangement whereby substitutes could be found if necessary and the expenses of travelling be met, which would enable geologists—particularly those in Government service whose movements so often are restricted by Service regulations—to travel beyond the boundaries of their own country so that they can examine outcrops or exposures which have a significant bearing on their work. Moreover, seeing for oneself, under competent

guidance, is of much greater value than to rely merely on descriptions of other observers.

Dissemination of information—The value to research workers of knowing what new progress has been made and techniques developed in their respective fields of inquiry needs no emphasis here. The problem is how can new scientific and technical information be disseminated or made available promptly and effectively.

The establishment of scientific liaison throughout the Commonwealth and the appointment of scientists as liaison officers to represent the different parts of the Commonwealth in order to facilitate the interchange of scientific information is a matter which no doubt will be presented by those who have already given it much thought in previous meetings. Perhaps the following suggestions might also receive attention in conjunction with recommendations submitted by other members of this conference for drawing up some comprehensive scheme designed to distribute promptly information on mineral research and exploration.

A central organization should be established to obtain and disseminate to members of the Commonwealth information concerning results of exploratory work, statistics of reserves, usage and requirements of minerals and other relevant data periodically.

The results of completed investigations, which will form the basis for further geological research and mineral exploration, should be published with the least possible delay. Serious delays, for example, are often experienced in the publication of the reports of Government science organizations. It is essential that there should be no delays in getting the results of a scientific investigation published if the maximum benefit is to be obtained. Information that remains unpublished for long periods usually defeats the purpose of many a painstaking piece of investigation or research work, and is of little service to the public welfare.

Selected officers should be sent abroad, possibly on an exchange basis to acquire knowledge of and make practical acquaintance with the latest geological and mining teaching, survey and research. This scheme, if adopted, should also further plans for the co-ordination of and mutual assistance in research programmes by making possible a more direct dissemination of knowledge through closer contacts with geologists in other parts of the Commonwealth.

The writer is indebted to Dr S. H. Haughton, Director of the Geological Survey, and to Mr E. M. M. Little and Mr W. L. Eales of the office of the Government Mining Engineer, whose constructive criticism, advice and interest in scientific research and mineral exploration and development have been most helpful in the preparation of this paper.

REFERENCES

The mineral resources of the Union of South Africa (3rd edition), Geol. Surv., Pretoria, 1940

Industrial minerals, *Quarterly Information Circular*, Dept. of Mines, Union of South Africa.

Annual reports of the government mining engineer, Dept. of Mines, Union of South Africa.

Report of the committee of inquiry into the base mineral industry of the Union. Government Printer, Pretoria, 1939.

Official year book of the Union for 1938 et seq. Chapter dealing with mining and mineral resources.

Third interim report of the Industrial and Agricultural Requirement Commission. Fundamentals of economic policy in the Union. Government Printer, Pretoria, 1941.

Publications of the Geological Survey of the Union of South Africa, particularly the *memoirs* and *bulletins*.

Bulletins and *memoirs* of the Government Metallurgical Laboratory (formerly the Minerals Research Laboratory), Dept. of Mines, Union of South Africa.

MORNING SUBJECT (1)

DISCUSSION OF THE NATURAL PRODUCTS OF THE EMPIRE AND THE CHEMICAL INDUSTRIES THAT ARE OR MIGHT BE BASED ON THEM

STEERING GROUP

Chairman and Recorder—Dr J. L. Simonsen, F.R.S.

Sir Jnan Ghosh
Professor E. J. Hartung
Professor O. Maass, F.R.S.
Mr F. E. V. Smith
Dr J. Smeath-Thomas
Professor F. G. Soper

REPORT

This discussion dealing with the utilization of the natural products of the Empire as a basis for chemical industries not unnaturally covered a very wide field. It was emphasized by all the speakers that the primary object of the application of research to these products must be to raise the standard of living of the peoples of the Empire. For this purpose the key substance was *water* and it was urged that a great expansion of the geological surveys and meteorological studies were essential if adequate supplies were to be made available. The importance of geology as the basis of soil surveys was referred to since such surveys were of the greatest importance to agriculture and for the prevention of soil erosion.

The agricultural products of the Empire provide an abundance of materials which can be used in the chemical industries. Among the primary products attention was directed to the importance of sugar and starch and to the long-term investigations now in progress both in Great Britain and elsewhere into the possibility of their increased use as raw materials for industry. One speaker drew the attention of the Conference to the importance of developing within the Empire the manufacture of furfural, a substance used both in the plastics and synthetical chemical industry. Materials for its manufacture, namely bagasse, maize cobs, palm kernel shells, are available in adequate quantity. In the discussion it was recognized that the recent developments in synthetic organic chemistry were likely to imperil the future use of plant products unless close collaborative research within the Empire was adequately supported and developed. Such collaborative research should apply also to animal and dairy products.

In the mineral field attention was directed to the importance of obtaining a much wider knowledge of the Empire's resources. Research was required more especially on the problems of processing low-grade ores.

The Conference recognized the need for close collaboration throughout the Commonwealth in the consideration of the problem of making the widest use of the raw materials which are available or could be grown in various parts of the Empire, and suggested that means should be provided for such collaboration.

GENERAL STATEMENT

In view of the varied nature of the natural products of the Commonwealth, their wide geographical dispersal and the diverse and often inadequate facilities in staff and equipment which may be available locally

for their investigation, the Conference makes the following recommendations :

RECOMMENDATIONS

1. That a standing central committee, including representatives of the United Kingdom, the Dominions, India and the Colonies, should be set up to advise upon policy for the co-ordination of research, both scientific and economic, into the natural products of the Commonwealth. Such advice upon their own particular problems would be made available to all Commonwealth countries with the minimum of delay.

2. The Conference, whilst recognizing the desirability of centralizing research upon problems common to many parts of the Commonwealth, supports very strongly the view that research upon problems of more local interest should be co-ordinated within regions. It is anticipated that this would lead to increased efficiency and economy in manpower. The Conference regards advice upon the concentration or regionalization of the research in question as an important function of the central committee.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr M. P. Applebey

Organic chemicals have been produced mainly from coal or mineral oil as ultimate raw materials, thus necessitating the drawing upon the capital resources of the world. The basing of manufacture of organic chemicals on agricultural raw materials would allow of production from raw material sources which are replenished annually. It may be argued, however, that in order to maintain soil fertility, fertilizers are needed and their production may involve the use of coal or oil, but the amount of carbon so used will be small in comparison with that used for the direct production of organic products.

Agricultural products are mainly used for food but they have to a lesser extent been used for the manufacture of chemicals, for instance, for the preparation of cellulose derivatives for fabrics, plastics, paints and explosives; vegetable oils for detergents and paints; sugar for the production of alcohol and other fermentation products; and recently proteins from ground nuts are being considered for the manufacture of 'Ardil,' a fibre with properties similar to wool.

In the preparation of food products, such as sugar, maize and vegetable oils, considerable quantities of waste materials become available, in some cases at centralized locations where the agricultural products are processed, and the use of these wastes, now used partly only as fuel, is considered to be attractive. In most cases digestion of these wastes with dilute acids converts the pentosan component into furfural. The residues can be returned to the land. In this case since no new tonnage of food crops is involved, there is no increased need of fertilizers. This process is operated in the U.S.A. using maize cobs, cotton seed hulls and oat husk, the installed capacity being 20,000 tons per year.

A survey of materials available in the Empire suggests such material as bagasse, coconut shell and husk, cotton seed hulls, maize cobs, rice husk and palm kernel shell as being among suitable materials and there are indications that productions of furfural in excess of 100,000 tons per year could be realized if required. In addition there are such plants as *Vossia Cuspidata* grass and the water hyacinth, which are at present a menace to agriculture, sanitation and the navigation of rivers and which have to be removed. These would be suitable for use in furfural production, and would increase the potential availability, several fold.

Apart from the use of furfural itself, the diagram on page 381 illustrates a few of the possibilities of chemical manufacture from furfural and draws attention to possible fields of application of the products. There are

considered here, only four of the primary reactions of furfural, whereas over twenty have been studied, leading on to several hundred chemical products.

It is sufficient for the present to indicate that the products developed, a number of which are currently being advertized as available in experimental quantities, may find wide application, for instance as solvents for paints, etc., plasticizers and even plastic materials themselves, ingredients of synthetic paints and varnishes, synthetic rubbers and fibres, and as medicinal intermediates.

What has been done with the pentosan content of agricultural materials can also be done with the hexosans of sugar, starch and cellulose. Here a promising intermediate is levulinic acid, from which, on account of its di-functionality a similar range of interesting chemicals can be made.

These fields of development are still in their infancy, but it is probable that in the next decade or so, the economic production of organic chemicals, along the lines indicated, will become a reality, based on the abundant raw material source of Empire agricultural products.

Lt.-Col. L. J. Barley

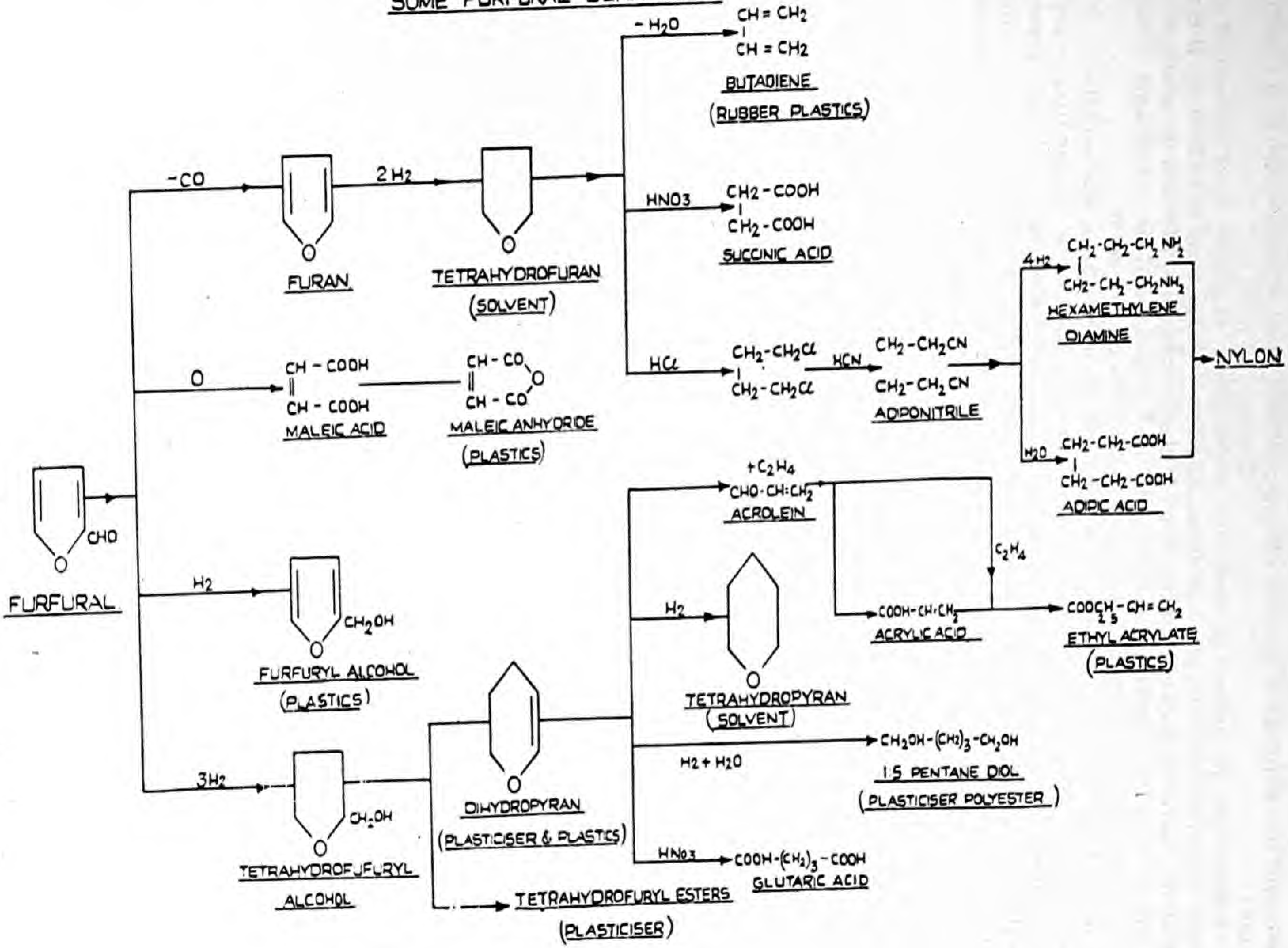
Our duty whether connected with science, industry, or government agencies is to see that scientific *and* economic—or technical and commercial—knowledge are systematized, welded together, and applied to the service of mankind. If this is not done production planning is sterile.

Before a new manufacture can be set up a plan is necessary based on (*a*) raw materials ; (*b*) a sufficient market ; (*c*) technical skill and directive efficiency. The present stage of our industrial development still involves bringing the raw materials to the centres where the markets are fully developed and where the technical skill exists. This necessitates that, for example, in the Colonial Empire and to some extent in India, scientific effort should be concentrated on the efficiency of agriculture and fisheries, and in the production of raw materials. This will, however, give rise to ancillary chemical industries. The most striking example is the projected production of ammonium sulphate in India. Some of us think that in order to prevent the possibility of famine within the next ten years, four million tons of ammonium sulphate with adequate distributive organization should be provided as against the projected three hundred and fifty thousand. Possibly by-products of oil production combined with plentiful gypsum supplies in Persia, might be included by our Indian friends in their survey of sources of nitrogenous fertilizers.

Cane sugar production gives rise to chemical manufacture in the logical sequence of alcohol used for power purposes, then as a raw material for solvent and plastics manufacture as the market develops. Alcohol is too valuable a raw material to be substituted for petrol. Bagasse is a promising raw material for furfural if an alternative cheap fuel for the sugar mills is available, the combustible residues providing fuel for the furfural process. Although the potentialities of furfural as a chemical raw material are vast, most of these depend on much cheaper supplies than are now available.

Agricultural and forest wastes such as straw, sulphite lye, lignin and palm kernel shells are only likely to be economically valuable as raw materials if they are already available in large bulk at one place. They

SOME FURFURAL DERIVATIVES



become too expensive if collected specifically and transported to a chemical plant.

Long term problems include the production of paper and chemical pulp from annual crops instead of from timber. Attention is called to the fact that by suitable forest exploitation India could provide much more of the Empire requirements of turpentine and rosin, and in so doing provide raw materials for further chemical industries of her own.

This Conference is laying foundations of scientific collaboration. One may hope that it will also make recommendations regarding mutual consultation and planning on specific matters bringing in those elements of directive and industrial knowledge which must be added to the scientific facts so that our resources of knowledge and ability may give rise to greater production and exchange of goods on which our prosperity depends.

Dr J. R. Furlong

I wish to refer to an aspect of this vast subject which has so far not been mentioned, namely, the presentation of the raw natural products to the manufacturer, to the chemical and other industries.

Firstly, the marketing of well-known materials from new origins. The introduction into commerce of a raw material not previously employed, is to-day, infrequent. It is very desirable to investigate the possibilities of natural products not hitherto utilized, and to conduct research on new applications of well-known products, but a more quickly profitable field of development is offered by the production of commercially known products in countries where they have not hitherto been grown or collected. Such productions may be regarded as new materials in a sense, since to the manufacturer a raw material from a new origin is virtually a new material, as he will not know its quality and suitability for his purpose. It is in this connexion that I would stress the importance of devoting attention of the highest order to the marketing of products from new sources which will compete with the descriptions already well established on the market. Apart from intrinsic quality, which of course must be satisfactory, the preparation, trimming, processing and packing must be that which custom or manufacturing requirements demand. In an open and keen market a low price may result through lack of attention in presenting a product which is otherwise of good quality. I therefore emphasize the advantage to be gained by correctly conforming to the purchasers' requirements, and for this purpose, the intimate study of the subject. It may be that investigation would advance the standard of marketing in some cases, and provide the consumer with the material in a better form for his purpose than he had previously obtained.

My second item is the potential wealth destroyed by faulty methods employed in collecting and preparing natural products. To mention one instance. Some years ago we estimated that through bad preparation the loss in value of hides and skins amounted to well over one million sterling. Wrong methods of drying and handling cause irrevocable damage to material which is of good natural quality. In this case the financial loss falls chiefly on the small producer, the African for instance, while the highly organized meat works and large abattoirs, fully aware of values, can employ satisfactory methods. The correct methods of preparation

have been worked out, but their adoption by scattered individual producers has so far presented organization difficulties.

This is but one example of dissipating natural wealth. In general, much could be gained by greater attention to the preparation of raw materials, and the raising thereby of the standard of quality and market value. In this connexion the biggest field for improvement will be found amongst industries consisting of small producers. With this subject is bound up the one of certification of quality by marking the produce with a recognized mark, applied authoritatively. The advantage to be gained financially by offering the consumer materials which he can purchase with confidence is manifest, and consideration of the wider application of such a system is to be recommended.

Dr S. L. Hora

Dr Hora remarked that the ultimate success of any primary industry based on natural products will largely depend on the proper utilization of its by-products. He gave as an instance the fish industry of Bengal and stated that at present the people would only buy round fish and not fillets. In the past, there were sound reasons for this practice, for in a tropical country one would like to be doubly sure that the fish one ate was of good quality. With the modern development of refrigeration and cold storage, if filleted fish could be made popular in Bengal, several industries, such as manufacture of glue from scales, of fish meal from bones, of oil from liver and entrails, of manure from offal, etc. etc., could be established with the result that the price of fish would come down. The low price would induce larger consumption of fish and thus greater development of the industry.

Dr Hora referred to the references that had been made to the need for conserving waters for the running of chemical industries and warned that natural water resources were also the reservoirs of fish. It was imperative therefore that in the construction of dams and weirs for the storage of river waters, adequate provision should be made for the movements of migratory fishes through fishways. He also stressed the desirability of treating chemical factory effluents before their discharge in natural waters. With the industrialization of any country, the risk of polluting natural waters was very great so he sounded a word of caution in this respect.

Dr Hora referred to the Tibetan wool trade that passed through India. The wool was full of impurities and some factory set up for its refinement at Yatung will not only save considerable transport charges but will also enable the by-products to be used in the country of production.

Dr Alexander King

Sir Ian Heilbron has stated that the Empire is finding new strength in its dispersion in small units throughout the world. I would like to suggest that, while this is at present only applicable in terms of defence, it may become a reality if we make use of the vast range of natural products and environments which are put at our disposal.

It seems to me a matter of primary importance in discussion of the utilization for industrial purposes of any particular colonial material, that we should consider the economic and sociological aspects of the problem

at the same time as the more directly scientific. In many instances economic conditions rule out the possible utilization of a process which may be technically sound, and hence research work commenced without taking proper cognizance of economic factors may be positively misleading. Similarly, sociological factors arising in a number of ways, such as those of a one-crop economy, may be important in steering technical development along sound lines.

I feel that the Dominions should be invited to take a greater interest in Colonial products research than has hitherto been the case. Their interests in other aspects of Colonial life are already great and in some instances even predominant. I would mention in this connexion the very large trade interests of Canada in the West Indies and those of our Southern Dominions in the development of the Islands of the Pacific. I therefore wish to support Sir Ian Heilbron's suggestion that the Dominions should be invited to participate in any central bodies responsible for Colonial research, and furthermore, that their help should be obtained in regional schemes.

A final point which I should like to make is the necessity for tackling urgent research problems for the Colonies in a central way. Many Colonial products are economically important in a number of Dominions and Colonies, and hence problems associated with their development should be susceptible of solution in one place on behalf of all. As examples, I would mention sugar, which is an important product of South Africa, India and Queensland, as well as of the West Indies, Fiji, Mauritius and other Colonies. The problems attending its industrial utilization are common to all these places. A further example is that of utilizing the kelps, which are found in abundance in Scotland and Ireland, in British Columbia, Tasmania, the Falkland Islands and elsewhere. The importance of this raw material has now become obvious, and much work is still required which could be done centrally on behalf of all sources of the raw material. I feel that to tackle such problems piecemeal is not the most intelligent approach.

Professor F. G. Soper

These remarks are only introductory to this subject as a fuller statement, prepared by Dr J. Melville on the 'natural products of New Zealand and chemical industries that are or might be based on them,' has already been circulated.

The special assets of New Zealand are her climate and soil resulting in an all the year round growth of grasses, in amount approaching double that in Great Britain and accounting for her position in animal and dairy production. Her other industrial asset is water-power, hydro-electric power now in use exceeding half a million horse-power with very great reserve potential for multi-fold extension. As yet, however, electro-chemical industry has not developed. Such development is handicapped by a relatively small home demand and the distance of overseas markets. Her population is one-twentieth that of the United Kingdom in a territory of approximately the same area, but spread out in two islands along a length of 800 miles.

Hence New Zealand's chemical industry is largely concerned with her

agricultural needs and with the processing of products derived from these primary industries. In chemical industries based on such products efficient processing is possible. To take one example, that of lactose production, high density of the dairying industry in certain parts of the country enables cheap collection of whey. From this New Zealand produced in 1945 1,000 tons of lactose, an amount which represents one quarter of the 1939 world production. Other such industries are the production of rennet, gelatine, and soap. In marine products shark-liver oil is processed to an amount equivalent in vitamin A content to half a million gallons of cod-liver oil.

The war stimulated numerous productions such as agar, medicinal plants, etc., and their future depends on the costs of alternative supplies. In this connexion New Zealand is interested in the possibilities of development of hormone products based on her frozen meat industry. It is probably true that future chemical industrial development lies along the path of greater utilization of our animal and vegetable (including forest) products and wastes.

The problem in Australia of the utilization of the potash and wool wax in greasy wool mentioned by Professor Hartung is also of interest to New Zealand. The reference to the wool scouring system used in the Schaken-Meyer and Mann works in South-West Germany reported on in F.I.A.T. Nos. 154 and 546 may be of interest.

Dr H. H. Storey

Speaking on the means for advancing industrial developments in the Colonies (the need for which was particularly acute in East Africa to meet a problem of severe agricultural over-population) Dr H. H. Storey urged the need for local scientific organizations to act as a link between research organizations in more advanced countries and local industry. The need was to interpret local materials and conditions to research, and to interpret research results to industry. Such interpretation would involve surveys of industrial opportunities, laboratory studies of materials and methods and similar applied investigations. Nothing of the nature of fundamental research would be undertaken locally in this field.

This proposal was not in conflict with Sir Ian Heilbron's views on the co-ordination of industrial research. Rather it was a necessary corollary, if the results of research were to be properly applied in the Colonies. Furthermore much industrial development would be in the application of well-known processes, in which research organizations would not be interested.

SOME POSSIBLE CHEMICAL INDUSTRIES FROM WOOD PRODUCTS IN CANADA

(Department of Mines and Resources, Lands, Parks and Forests Branch, Dominion Forest Service, Forest Products Laboratories).

Introduction

It is a little difficult to discuss both actual and potential industrial chemical uses for wood and divorce the subject entirely from the pulp and paper field. For example, many products obtained by treating cellulose and lignin *in situ* by various chemical techniques can generally be obtained, and often with greater ease, from celluloses and lignins isolated by chemical pulping processes. However, an attempt will be made here to cover only subjects which have probably not been or will not be treated by pulp and paper experts.

Hardwood distillation

Destructive distillation is accomplished by heating wood out of contact with air, that is in a non-oxidizing atmosphere, under which conditions the wood decomposes, yielding a residue of charcoal and considerable quantities of gases. The gases on cooling are partly condensed to liquids and the remainder are uncondensable. Acetic acid, methyl alcohol and wood tar are derived from the liquid condensate ; the uncondensed gases are burnt as fuel. The wood tar is burnt as fuel, but is a potential source of valuable chemicals.

The species usually employed in Canada are the heavier hardwoods, maple, beech and yellow birch. The gathering of wood for distillation often accompanies lumber operations, small trees, limbs, etc., that are unsuited for lumber, being utilized.

Before and during World War I the hardwood distillation industry was in a thriving condition in Canada, but since this period synthetic methods have been devised for the production of the most important products, acetic acid, acetone, methyl alcohol and formaldehyde. Hence, the only remaining product that cannot be produced from other sources than wood is charcoal. The production of these synthetic materials has resulted in lower prices. When to this there is added the greatly increased cost of delivering wood to the distillation plants, the overall result is that the wood distillation industry finds it very difficult to operate at a profit. A further bad feature is that the market for charcoal produced in Canada is very limited.

Charcoal is also produced in considerable quantities in Canada, especially in the Province of Quebec, by the charcoal burning process where the hardwood is stacked, usually in small brick kilns of 10 to 12 cords capacity,

and by regulating the air supply some of the wood is burnt producing sufficient heat to decompose the remainder of the charge. The only product obtained is charcoal. The advantage of this process is that small, low cost units can be built near the source of wood supply.

Naval stores

Chief products of the industry are now turpentine and rosin, whereas originally they were wood tar and wood pitch. There are no naval stores produced in Canada, except a small quantity of turpentine as a by-product of the pulp industry.

Naval stores are produced either from living pine trees by the process, known as ' turpentine orcharding,' involving the tapping of pine trees to catch the gum that exudes, or from the stumps remaining from cut-over pine forests selected for high resin content. Considerable quantities of Ponderosa pine are available in British Columbia, and this pine gives a good yield on tapping. However, yields depend on temperature conditions, the gum only exuding in warm weather, hence lower annual yields are to be expected in Canada than in the Southern United States where tapping can be carried out during most of the year.

Naval stores from pine stumps are obtained by two processes :

(*a*) Destructive distillation, whereby the wood is distilled just as in the case of hardwoods described before. However, the valuable portion is the tars which on distillation yield turpentine, pine oil, pine tar, and pine pitch. This process is rapidly being superseded by :

(*b*) the solvent process. In this process the resinous stumps are converted to chips and extracted with suitable organic solvents. The solvent is removed by distillation and the residue yields turpentine, pine oil and rosin.

It would seem that the most likely source of naval stores in Canada is from the selected resinous waste of sawmills cutting pines. This selected waste might be treated by the solvent process to yield naval stores.

The Western Pine Association Research Laboratory, Portland, Oregon, has carred out experiments on the seasoning of pine lumber by extracting with an organic solvent such as acetone. Not only is the moisture content reduced, but valuable materials, such as turpentine, rosin and fatty acids, which are not an integral part of the wood structure, are extracted. Should such a process develop and be applied in Canada, it would be a source of naval stores and fatty acids.

Essential oils

Volatile oils, known as essential oils, can be prepared from the leaves and twigs of trees by distillation with steam. This industry has not a large market but a considerable number of small producers in Canada prepare essential oils from the leaves of white cedar, spruce, balsam, hemlock and pines. Such oils, prepared during the war and the present post-war period, are finding a ready market at good prices, but in the pre-war period the demand for these oils was not very large and the prices were very much lower than at present.

Canada balsam and spruce gum

A small, steady market exists for these products produced in Canada by many small producers. Canada balsam is collected from the blisters occurring on the bark of balsam fir ; it is mainly used for cementing together various parts of optical instruments. Spruce gum is collected from spruce trees where it exudes as a result of wounds ; it is used in medicinal preparations and as chewing gum.

Tannins

Tannins form compounds with hide fibre which are resistant to washing, and large quantities of vegetable tannins are required in the leather industry. Tannins may be obtained, by extraction with hot water, from the bark, wood and leaves of a number of Canadian species. At one time considerable tannin was obtained in Canada from the bark of eastern hemlock, but production has dwindled to a low point. In Western Canada there exist important stands of several different species, the bark and wood of which are known to contain a high percentage of tannin ; especially is this true for western hemlock and there seems no doubt that tannin suitable for the leather industry could be obtained from the bark of this species.

Wood saccharification

In the acid hydrolysis of a cellulosic material such as wood, there is obtained glucose as the main carbohydrate constituent, with lesser quantities of sugars such as xylose, mannose, arabinose and galactose. In the commercial hydrolysis processes in operation in Germany before and during the war, the fermentable carbohydrates obtained from wood were converted to yeast or ethyl alcohol. However, other fermentation products such as butylene glycol, butanol, acetone and organic acids, can be produced if desired.

The production of sugars from wood has attained commercial status in North America in the past, but the process did not seem to be able to survive our changing economic conditions. In Germany, with its government subsidized industry during the Nazi regime, two processes were used fairly extensively, namely, the Bergius and Scholler. The former uses high concentrations of acid at room temperature and atmospheric pressure producing almost the theoretical yield of reducing sugars available in the wood. The Scholler process employs low acid concentration, high temperatures and pressures, and gives about 75 per cent of the theoretical yield of reducing sugars available. It is generally believed that the Scholler process is the more economical of the two. On the American continent neither process is considered to be economically advantageous as there are cheaper sources, such as molasses, for sugars.

On the United States Pacific Coast a hydrolysis plant was erected towards the end of the war for the production of alcohol from sugars obtained by treating wood by a modified Scholler procedure. It will be interesting to learn how this process will fare in our post-war economy. There is still considerable room for improvement in the process, particularly in the finding of a use for the by-product lignin, and also in fermenting the sugars to products other than ethyl alcohol.

Whereas it is optimistic to think that the hydrolysis of wood for the production of sugars is an established industry, yet it is one that we should at least hope for. If this industry could be properly established, it would go a long way towards solving the lumber industry's waste wood problem. As an example of the amount of wood that is involved, it might be pointed out that the one plant on the United States Pacific Coast will use 350 tons of waste wood per day when in full operation.

Action of alkali on wood

If wood is treated with aqueous caustic solutions at high temperatures and pressures, there are produced methanol, acetone, acetic acid, formic acid and oils.

Oxalic acid may be produced from wood in several ways. A former commercial process involved the caustic fusion of sawdust. Although other methods of oxalic acid production are in use to-day, experiments have recently been carried out with the aim of reviving the caustic soda fusion process. Othmer and his associates at the Brooklyn Polytechnique Institute have developed a continuous process for oxalic acid formation from sawdust in which it is claimed that yields of 65 per cent can be obtained in plant-scale operations. Acetic acid and formic acid by-products are obtained in yields of 18·9 and 3·86 per cent respectively. Sodium soaps of fatty acids are also present in the fusion mixture in amounts equal to 2 to 3 per cent of the weight of the sawdust.

Wood waste utilization

At the outset of every discussion on wood waste utilization it has to be made clear that every process which eventually will have a chance to become industrially important has to aim at products which are needed in large quantities. Products which sell at a high price per unit, but are of limited application, might be of interest for a single manufacturer as a side line, but do not contribute to the general problem of wood waste utilization. (Example : vanillin from sulphite waste liquor.)

Manufacture of boards from sawdust and lignin, transformation of partially pulped sawdust into structural material, production of chemicals from lignin, livestock fodder from sawdust by removal of a part of the lignin, and manufacture of fertilizers and insecticides are examples of processes which could provide outlets for vast quantities of waste.

A few remarks on some of these suggested fields of development are given hereafter :

Boards from sawdust and wood waste

It is not intended to review the well established processes for softboards and hardboards from wood fibre.

Lately some publicity has been given to a process by Smith and Othmer for the manufacture of a useful hardboard from sawdust and sulphite waste liquor. The process is not yet in technical operation in Canada.

Cheap potential binders for sawdust are blood (either fresh from slaughterhouses or in the form of dried soluble blood) and vegetable proteins,

especially the residue from the castor bean after oil extraction. The boards are of limited strength, but may have a certain field of application. Although there are technical difficulties in preparing structural board from alkali lignin and sawdust, there are good possibilities that such a process will provide a large outlet for these materials.

Hydrogenation of lignin

The utilization of huge amounts of organic matter in the waste liquors obtained in pulping operations has made very little progress so far. One of the reasons for this is the fact that the main constituent lignin, is very resistant to chemical attack.

From the work of Adkins, Harris, Freudenberg, Hibbert, *et al*, it is known that lignin can be hydrogenated. The resulting compounds are mainly derivatives of cyclohexanol. The work done so far has been mainly concerned with the elucidation of the chemical structure of lignin and has had no immediate bearing on the practical industrial problem of lignin utilization. The conditions to which lignin has to be subjected in order to be hydrogenated are so severe that a process on an industrial scale would become economically impossible due to the high costs of apparatus.

These laboratories have for a long time considered the possibility of the hydrogenation of lignin electrolytically, and preliminary work is under way, especially with the object of hydrogenating the calcium-ligno-sulphonate as contained in waste sulphite liquor.

Physical conditions at the cathode can be varied over a wide range. Electrode potential, current density, concentration, temperature, material of the electrode, additions to the electrolyte and diaphragm are the main variables. The chemical use of cathodically developed hydrogen has many possibilities.

Besides the possibility of cathodic hydrogenation, a number of interesting processes could be carried out simultaneously at the anode. Oxidation of the sugars present to gluconic acid and chlorination of the organic compounds after the addition of chlorine ions are mentioned in this connexion.

Since many pulp and paper plants have their own power stations with suplus power readily available, the installation of electrolytical cells might contribute to a more economical utilization of wood in the pulp and paper industry.

Microbiological utilization of wood waste

For centuries certain microbiological processes have been applied in the manufacture of bread, wine, beer, vinegar, cheese, etc. It is, therefore, rather amazing that further applications of processes which are brought about by the action of micro-organisms are very limited.

In the specific field of wood waste utilization, we are applying yeasts to hydrolyzates of wood. Aerobically we produce yeast, a rich source of proteins ; anaerobically we obtain ethyl alcohol. There is no reason why certain glycol producing bacteria, which so far have been grown on starch or sugar from other sources, could not be cultivated on wood hydrolyzates.

In the following lines suggestions are made which are intended to form the base for some discussion :

(*a*) The process which is going on in the digestive tract of wood-digesting insects could serve as an example for the possible microbiological digestion and transformation of wood into valuable materials, e.g. proteins. The protozoa and bacteria which live within the insects should be investigated with the aim of utilizing them in large-scale industrial operations.

If it were possible to incubate sawdust, to which all the chemicals and growth factors required have been added previously, and which could be kept under suitable conditions of moisture, pH, temperature, etc., production of proteins, fats, carbohydrates and various chemicals from sawdust should become feasible.

(*b*) The microbiological digestion of organic matter as applied in sewage disposal plants often leads to mixtures of carbon dioxide with methane and hydrogen. The latter, being available in the nascent state, might be utilized directly for biological hydrogenations. If, for example, hydrogen producing bacteria could be grown in sulphite waste liquor which contains approximately 2 per cent of sugars, the nascent hydrogen produced by the bacteria might combine with the lignosulphonic acid, the microbiological system acting simultaneously as a catalyst between hydrogen-donor and hydrogen-acceptor.

Uses of wood waste in agriculture

Many arguments have been brought forward as to the merits of sawdust as a soil conditioning and fertilizing agent. The generally accepted opinion is that sawdust and shavings are excellent as absorbents for liquid manure and (if available) should be used for bedding of animals . The function of sawdust in bedding is a mechanical one only. It absorbs the nutrients of the manure and makes their transfer to the land more efficient.

The effect of sawdust itself on soil is threefold :

(*a*) It causes increased activity of micro-organisms due to its content of soluble substances, hemicelluloses and celluloses. As the micro-organisms utilize some of the available nitrogen for the synthesis of their proteins, a temporary decrease of available nitrogen results.

(*b*) The bacteria from the above mentioned activity decompose slowly, making available the nitrogen of their proteins.

(*c*) The lignin part of the sawdust decomposes very slowly. This process is known as humus formation and has great importance for the texture of the soil. Besides the loosening effect, which is especially desirable in heavy soils, it increases the base exchange capacity and the water retaining capacity of soils.

A SURVEY OF INDIAN CHEMICAL INDUSTRY IN RELATION TO RAW MATERIALS AND OTHER EXISTING INDUSTRIES OF INDIA

By Sir Jnan Ghosh and D. N. Wadia, M.A.

Manufacture of chemicals—a key industry

Chemical industry produces materials which are mostly used in other industries or in agriculture. In that sense it is a key industry. India manufactures a considerable portion of her requirements of ordinary consumers' goods like textiles, soap, leather, paper, sugar, glass and ceramics, paints and varnishes, drugs, rubber goods, hydrogenated oils, etc. Indian manufacturers are anxious that the chemicals which are necessary for the processing of these commodities should, as far as possible, be produced in India. Lack of essential chemicals during the last war has been detrimental to the growth of these industries ; and it is rightly felt that it would be unwise to depend on foreign countries for their supply.

Textile industry

The pre-war production of woven cotton goods in India was 900 million pounds. Under the stress of war, with many mills working under double shift, the production has been raised by 40 per cent approximately. Our pre-war requirements of dyestuffs and accessories was of the order of £1·3 million. Besides dyestuffs, the textile industry consumes large quantities of chemicals, like sodium carbonate, caustic soda, bleaching powder, hydrogen peroxide, sodium sulphide, sodium hydrosulphite, and sizing materials like starch and magnesium chloride. The wool industry has made considerable headway during the war, and it is intended to establish several rayon factories producing 60 tons a day within the next five years. The latter will require pure caustic soda, carbon disulphide, acetic acid and acetic anhydride, sulphuric acid, chlorine, and numerous other chemicals.

Soap industry

Production of soap in India increased from 94,000 tons in the first year of the war to 160,000 tons in 1944. It is probable that the production will increase to 240,000 tons in 1951. In some of the modern factories only, glycerine was recovered to the extent of 1500 tons which was mostly consumed for war purposes. The principal chemicals needed in this industry are caustic soda, caustic potash and essential oils. During the quinquennium ending 1938–1939, India exported essential oils worth 4·6 million rupees, and imported perfumes worth 2·2 million rupees. The former mostly consisted of lemongrass and sandalwood oils.

Leather industry

India is the world's biggest producer of hides and skins. The pre-war production amounted to 20 million cattle and 3½ million buffalo hides, plus 22 million goat and kid skins and 3 million sheep skins. Much of this material was exported in a raw, dry, salted state. Modern tanning for producing saddlery and military equipment and sole leather, using myrobolans, babul (acacia) bark and imported wattle bark has made remarkable progress. Chrome tanning has also developed at a phenomenal rate ; high-class glacé kid, box and willow sides from cow hide, box and willow calf, not only supply India's own requirements of leather goods, but are exported in increasing quantities to neighbouring countries and also to the United Kingdom. It is intended that the export trade in raw hides and skins should be replaced as soon as possible by the export of finished and semi-finished leather. The principal chemicals required for this industry are chromates, tannins, sulphides, salts, lime, etc.

Paper industry

It is interesting to note that Indian paper is mostly manufactured from bamboo and not from wood. The advantage of bamboo as a raw material is that the cutting rotation is on an average four years. The quantity of bamboo available from surveyed areas in India now exceeds 600,000 tons, capable of producing 250,000 tons of paper a year. The present production of paper is 62,000 tons per year. The paper industries panel of the Government of India have recommended that this production be doubled in five years. The principal chemicals required for the industry are caustic soda, bleach liquor, sulphite, sulphate, magnesia, kaolin, etc.

Sugar industry

Protection was given to Indian sugar in 1932 and the development of the industry since then has been remarkably rapid. The average production of white cane sugar in India now is 1·2 million tons while the total estimated yield of raw sugar (gur) is 3·5 million tons. For the manufacture of sugar, the principal chemicals required are high grade lime, sulphur and carbon-dioxide. The average production of molasses in India is of the order of 500,000 tons. A considerable portion of molasses is now being used to produce power alcohol which is used in many parts of India as 10 to 15 per cent admixture in petrol. It is intended that the entire output of molasses should be converted into some 20 million gallons of power alcohol within the next five years. Alcohol and fusel oil therefore will be available as by-products of the sugar industry.

Glass and ceramics

Indian production of glass and glass-ware was at a conservative estimate worth 20 million rupees in 1941. It has increased considerably since then. Soda ash and lime are the principal chemicals required for the industry. There are some twelve factories in India manufacturing fairly good pottery articles, e.g., sanitary ware, electric porcelain, crockery, decorated vases and other utility articles. Total indigenous production is small compared with imported ware which in normal times was valued at 5 million rupees

approximately. Refractories needed for metallurgical industries have, under the stress of the war, been manufactured in India ; and high grade fire bricks, sillimanite bricks, magnesia and chromite refractories are now available from Indian sources. A Glass and Ceramics Research Institute has just been established in Calcutta by the Council of Scientific and Industrial Research, Government of India.

Paints and varnishes

The Indian industry produced on an average during the war, 60,000 tons of paints and varnishes. The average pre-war imports amounted to 19,000 tons valued at 9 million rupees. The principal chemicals required are (*a*) pigments like barytes, white lead, zinc white, titanium white, red ochre, red lead, chrome greens, chrome yellow, ultramarine, graphite, carbon black, etc. ; (*b*) solvents like turpentine, alcohols, acetone, petroleum distillates ; (*c*) lac, rosin, copals, gums, waxes, bitumens, glues ; and (*d*) drying oils, e.g., linseed oil, dehydrated castor oil, cashew-shell oil, etc. It is interesting to note that India is a large exporter of the drying oils, lac, rosin, turpentine, chromite, ilmenite, ochre, etc.

Drugs

The average pre-war imports of drugs into British India were valued at 22 million rupees which dwindled to 14 million in 1942–43. In 1943, India's output of medical stores rose to 60 per cent of her requirements. There has been much progress in the production of tinctures, extracts, galenicals, vaccine, sera and glandular products, but the industry has made little headway in the manufacture of synthetic chemotherapeutic products, vitamins and hormones. Natural drugs like quinine, morphine, codeine, strychnine, ephedrine, caffeine, santonine, and emetine are being produced in large quantities and partly exported.

Rubber goods

Indian production of raw rubber is 17,000 tons on an average as against pre-war world production of 14 million tons and probable production of synthetic rubber in 1943 of 700,000 tons. This comparatively small industry was, however, of great service when on entry of Japan into war, Malaya and East Indies passed into enemy hands. The principal chemicals required for the rubber industry are acetic acid, ammonia, sulphur, carbon disulphide, and various fillers, pigments, accelerators and anti-oxidants.

Hydrogenated oils

India produced 130,000 tons of hydrogenated oils for edible purposes in 1943. It is believed that the production will increase to 300,000 tons in five years. The important chemicals required for this industry are hydrogen, caustic soda, and nickel catalysts. Where hydrogen is obtained by electrolysis, oxygen is a by-product which becomes available for engineering industries.

Engineering industries

Along with industrial oxygen, large quantities of acetylene are required for engineering industries. Calcium carbide is an essential chemical whose import rose to 7,000 tons at the later phases of the war. The Government of India have decided to protect this industry if the material is manufactured in India.

Agriculture

The famine in Bengal in 1943, and the present famine in South India (1946) have focussed attention on increased food production in India. One of the methods of attaining this objective is to apply synthetic fertilizers to the soil. Ammonium sulphate has been found to be the most useful nitrogen fertilizer for India. Phosphatic fertilizers obtained from bones and rock phosphates by treatment with sulphuric acid or by heat treatment of phosphatic ores with fluxes are expected to be in great demand in the near future. For the preservation and storage of food grains, insecticides like carbon tetrachloride and paradichlorobenzene will also be needed.

Public health activities

It is probable that the future Government of India will make a determined effort to improve the health services and eradicate the pests which are carriers of malaria and other diseases. The war in the jungles of North-East India has brought home the efficacy of the new methods of extermination of insect pests based on the use of pyrethrum and D.D.T. Large scale production of these insecticides has accordingly been suggested.

Five year target for the production of chemicals

The Panels of Chemical Industries set up by the Planning and Development Department of the Government of India have on the basis of our needs, as indicated above, fixed the targets of production of some of the major chemicals as listed in the table.

Raw materials

Most of the raw materials needed for chemical industry are available in India. Some of them have been indicated in the appended maps. Salt, limestone, gypsum, bauxite, magnesite, chromite, manganese ore, zircon, kaolin, sillimanite, barytes, fluorspar, etc., are abundant and of high quality. In fact, in the production of ilmenite, monazite and beryl, India holds a strategic position. Phosphatic ores occur in two patches, in the North-East and South India, and are of medium quality. Indian production of coal has increased to 28 million tons per year. Most of this coal is raised from the fields of Bengal and Bihar. High ash non-coking coals are also raised in the Central Provinces, and Hyderabad and to a smaller extent in the Punjab and Orissa. Tertiary coal is available in large deposits in Assam, but the high sulphur content (5 per cent) of this coal

limits its utility. The installed coking capacity of high temperature coke ovens is 3·5 million tons of coal per annum which may yield 3 million gallons of crude benzol. The coke is mostly used for making pig iron and its subsequent conversion into 1·4 million tons of finished steel. In view of the large import of petrol into India the fullest use of benzol should be made as liquid fuel ; and the Government is being pressed hard to encourage the entire recovery of this benzol by fixing a fair selling price. The possibility of low temperature conversion of coal into semi-coke (for use as domestic fuel) which will yield simultaneously considerable quantities of tar and ammonium sulphate as by-products is under investigation. A recent discovery of lignite in South India may make possible the establishment of ammonium sulphate, soda ash and phosphatic fertilizer industries in that part of India, based on the local production of sea-salt, phosphates and gypsum of Trichinopoly and good limestone of Tuticorin.

India's resources in sulphur are very poor. Under the stress of the war intensive surveys were made of the deposits in Baluchistan, but the results were disappointing. Pyrites in small patches occur in the Simla Hills, Bihar and the Nilgiris but are not dependable. Sulphuric acid is therefore mostly manufactured from imported sulphur. There are, however, extensive deposits of high grade gypsum. It is probable that the Government may put up a model factory of their own which may yield valuable data on the economics of the production of sulphuric acid and of sulphur from Indian gypsum.

India's resources of copper and zinc are poor ; salts of these metals can be produced economically only from waste or secondary materials.

Immediately after the Bengal famine, the Government decided to establish a factory for the production of 350 thousand tons of ammonium sulphate. Accordingly a British technical mission visited India and recommended the establishment of a factory in Bihar where hydrogen will be produced by the action of steam on local coke, and ammonia converted into ammonium sulphate with the aid of gypsum brought by rail from North-West India. The construction of this factory has started. Under the auspices of the Travancore Government and with the technical assistance of American chemical engineers, another factory for producing 50,000 tons of ammonium sulphate is under construction near Cochin Harbour. The factory will utilize the gypsum deposits of South India and wood from the tropical forests of Travancore for the production of this fertilizer.

The Council of Scientific and Industrial Research appointed in 1941 a Committee to explore the possibility of manufacture of dyestuffs in India, with Sir Ardeshir Dalal as Chairman. Representatives of the Imperial Chemical Industries were associated with that Committee as advisers. The Tatas have decided to implement the recommendations of that Committee, and we understand that negotiations have been completed for starting a dyestuffs industry in India on a comprehensive scale in collaboration with the Imperial Chemical Industries.

The prohibition of exports of ilmenite and monazite sands as such, is under consideration ; and if this proposal materializes, it is probable that chemical industries based on these raw materials will soon be started in the State of Travancore.

ELECTRO-CHEMICAL AND ELECTRO-THERMAL INDUSTRIES

Electro-thermal and electro-chemical processes for manufacture of goods have recently made considerable progress in India. The installed generating capacity of electric public utilities in 1942 was 1,222,000 kW. This was exclusive of power generated in factories or collieries. About 200,000 kW have been added since then. Cheap hydro-electric power has made possible the production of industrial hydrogen by electrolysis in Mysore, of alkali and chlorine in Madras, and of aluminium at Travancore by electro-reduction of alumina. In the immediate post-war period, expansion of generating capacity would probably proceed at the rate of 15 per cent per annum. Specially promoted industrial loads are therefore under serious consideration, e.g., it is intended to make aluminium at the rate of 20,000 tons a year, electrolytic copper at the rate of 15,000 tons, electric furnace steel at the rate of 60,000 tons and other electro-thermal products like alloy steels, ferro-chrome, ferro-silicon, graphite, carborundum, etc. These industries were started on a small scale during the war, and their rapid expansion is probable in view of an assured market within the country itself.

[TABLE

TABLE

chemical	present production in tons	installed capacity in tons.	five year target in tons.	remarks
acetic acid	400		18,000	for rayon and dyestuffs industry.
acetone	1,000		12,000	for rayon dyestuffs and paint industries
alcohol	1 million gallons	2·5 million gallons	20 million gallons	power alcohol and solvent
ammonia	1,500		120,000	for use in refrigeration, and for conversion into ammonium sulphate, ammonium chloride, urea and nitric acid
ammonium carbonate	nil		600	
ammonium chloride	nil		4,000	
ammonium sulphate	25,000	(coke oven by-product 20,000)	425,000	for use as fertilisers
barium chloride	100		1,500	
benzene	?	4,500	4,500	for use in dyestuffs industry
calcium carbide	nil		7,000	
carbon disulphide	nil		9,000	for use principally in rayon industry
caustic soda	10,000	17,000	120,000	45,000 by electrolysis, 75,000 by causticizing
chlorine	8,000	15,000	40,000	for use in bleaching, in manufacture of insecticides and other chlorinated products.

TABLE—*continued*

chemical	present production in tons	installed capacity in tons	five year target in tons	remarks
chromates and dichromates .		7,000	7,000	
glycerine	1,500		2,000	
hydrochloric acid. . .	2,500 (30%)	..	3,000 (30%) 500 (100%)	for dyestuffs industry
magnesium chloride . .	7,000	..	7,000	
magnesium sulphate . .	4,000	..	4,000	
methanol	100	..	400	
naphthalene . . .	600	..	3,000	for use in dyestuffs industry
nitric acid	1,300	..	3,500	
phosphorus . . .	nil	..	3,500	by electro-thermal reduction of rock phosphates for conversion later into phosphoric acid and phosphates
phenol . . .	25	..	150	
potassium chloride . .	nil	..	3,000	for use as fertilizer
potassium chlorate . .	1,700	..	3,000	
potassium nitrate . .	15,000	..	?	saltpetre produced in cottages
potassium permanganate .	10		30	
salt	out of a total 2·5 million tons, 200,000 tons are purified for use in industry		500,000 of purified salt	

TABLE—*continued*

chemical	present production in tons	installed capacity in tons	five year target in tons	remarks
soda ash	38,000	74,000	150,000	
sodium sulphate	2,000		6,000	available as natural deposits in Rajputana
sodium sulphide	?		8,000	for use in textiles, dyestuffs, leather, paper, etc.
sodium hydrosulphite	?		3,000	
sodium silicate	3,500		4,000	
starch	20,000		30,000	
sulphuric acid	77,000		150,000	
sulphate of alumina	20,500		38,000	
sulphate of iron	2,000		2,000	
sulphate of copper	900		900	any excess required for agriculture to be imported.
super-phosphate	10,000 (?)		30,000	
toluene	1,000		1,000	for use in dyestuffs industries
urea	nil		10,000	for syntehtic resins and as fertilizer
zinc chloride	300	700	2,000	

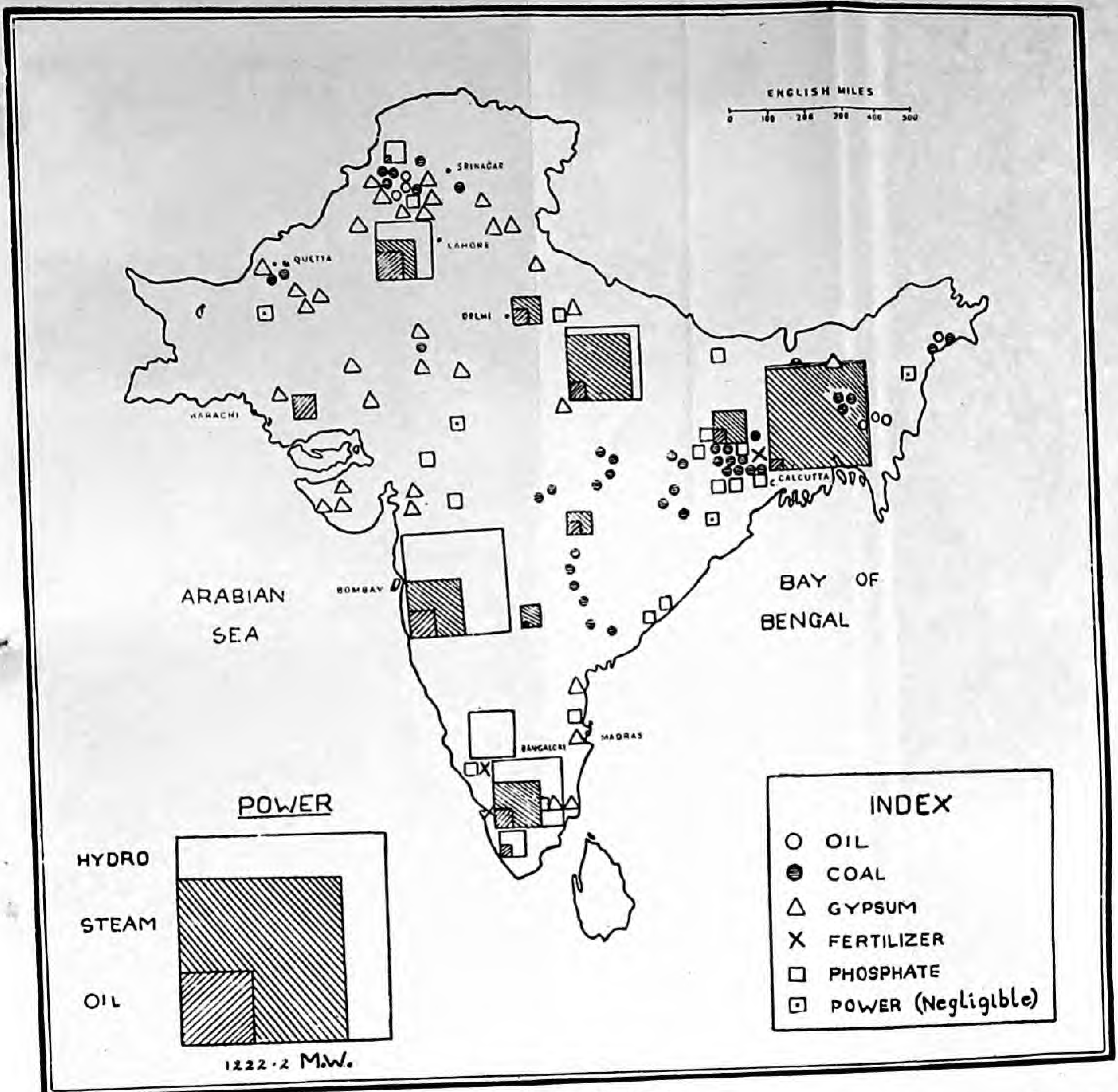

ENGLISH MILES
0 100 200 300 400 500
SRINAGAR
LAHORE
QUETTA
DELHI
KARACHI
CALCUTTA
BOMBAY
ARABIAN SEA
BAY OF BENGAL
MADRAS
BANGALORE
POWER
HYDRO
STEAM
OIL
1222·2 M.W.
INDEX
OIL
COAL
GYPSUM
FERTILIZER
PHOSPHATE
POWER (Negligible)

FIG. 1. POWER

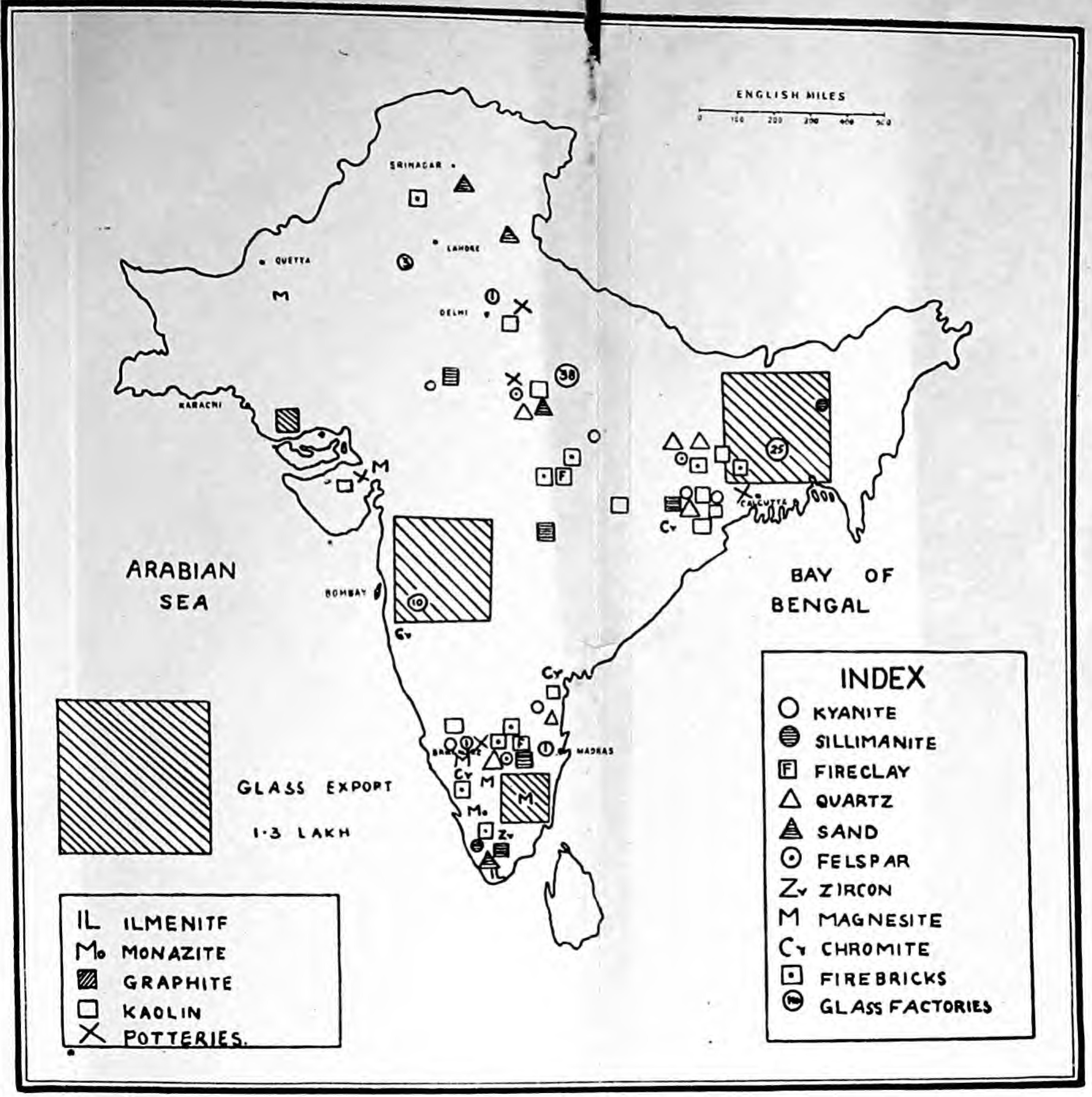


FIG. 2. MINERALS. I.

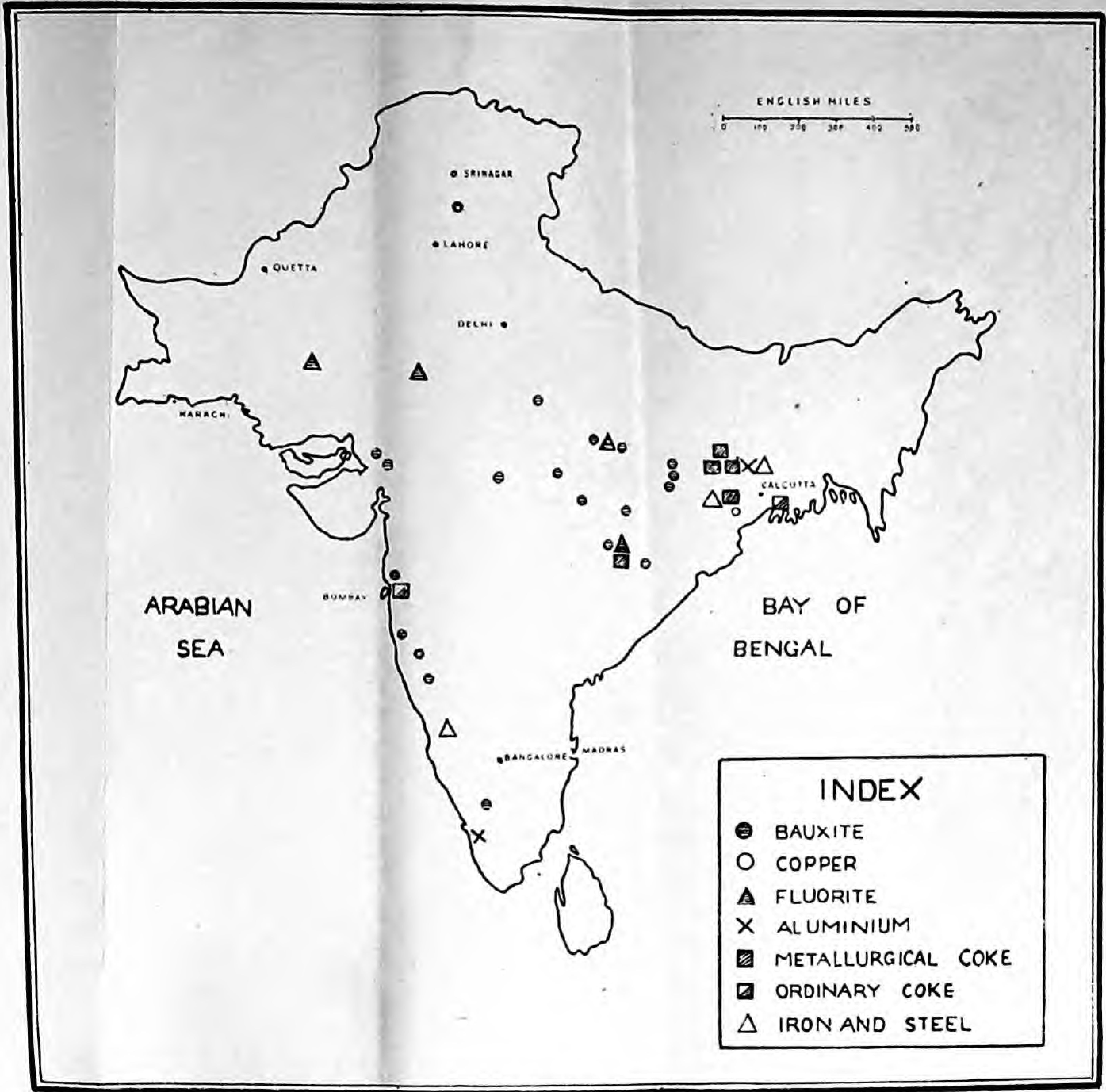


FIG. 3. MINERALS II.

FIG. 4. CHEMICALS.

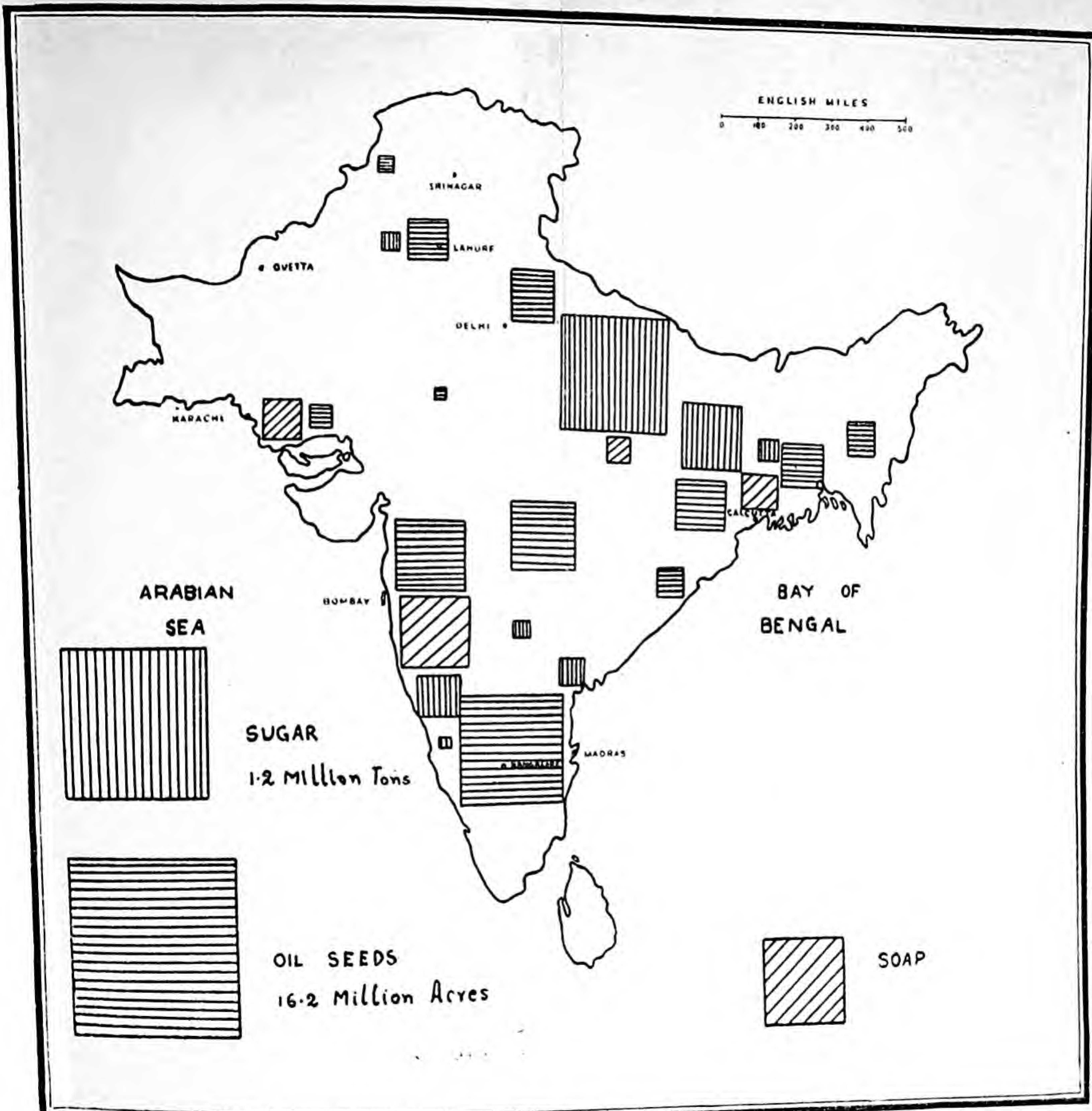


FIG. 5. SUGARCANE AND OIL SEEDS.

NATURAL PRODUCTS OF THE EMPIRE AND THE CHEMICAL INDUSTRIES THAT ARE OR MIGHT BE BASED ON THEM

By Professor E. J. HARTUNG, D.Sc.

(Professor of Chemistry, University of Melbourne)

THIS report deals briefly with the utilization of some of the natural products of Australia, excluding minerals and coal. Selection has been necessary, and only products and wastes of major importance have been included; moreover, the treatment is general rather than specific, as being more suited to the needs of the conference for which this report is written.

The subject matter is treated under the following divisions:—

1. the wool industry
2. forest products
3. straw and agricultural wastes
4. sugar-cane products
5. fellmongery wastes
6. seaweeds and fisheries.

1. WOOL INDUSTRY

Wool production is the greatest single industry in Australia, and as by-products to the scouring of natural greasy wool suint and wool-wax are obtainable. The former is the name given to a complex mixture of potassium and other soaps accumulated in the fleece from the perspiration of the sheep; the latter denotes the wool-grease consisting chemically of a complex mixture of cholesteryl and other esters which are essentially waxes rather than fats. The average annual Australian clip of greasy wool contains about 80,000 tons of wool-wax and 30,000 tons of suint.

Suint is soluble in water, but wool-wax is insoluble, although it may be emulsified in water very readily. In the process of wool scouring with soapy or alkaline liquors, the wool-wax and suint pass into the wash waters and produce a very troublesome industrial effluent. In the past, efforts at recovery of the wool-wax have been directed mainly to improving the quality of the effluent so as to render it less objectionable for municipal disposal. Various processes of recovery have been tried and are in use, such as treatment with acid, centrifugal separation, forced aeration and flotation. By these means, 50 per cent or more of the wool-wax may be recovered, but the valuable potassium salts are lost; treatment is not cheap owing to the large volumes of dilute effluent which must be handled.

Solvent extraction of the wool itself has therefore been tried in Europe and America, though British practice has been conservative in this regard. Hydrocarbon or chlorinated hydrocarbon solvents are used before or after

water extraction; by these means very good recovery of the wool-wax and potassium salts is obtained, and the wool is left very clean and in good condition provided that a small amount of the wax is left in it to keep it soft. Expensive plant for extraction and solvent recovery is needed, but the process has much to commend it, although opinion is divided on the relative merits of scouring and solvent extraction.

Purified wool-wax is marketed in lanoline, and finds use, medicinally, in cosmetics and as a rust preventive; it is a rich source of sterols (a group of compounds which have a profound effect on human metabolism) and of higher alcohols and fatty acids generally. Suint is a source of potassium salts and fatty acids. It seems clear that from these wool-products many useful substances might be obtained either directly marketable or capable of serving as intermediates in organic chemical industry. A thorough investigation is being undertaken by the Industrial Chemistry Division of the Council for Scientific and Industrial Research of Australia. At present, of the 15,000 tons of wool-wax potentially available in wool scoured in Australia, only about 450 tons are saved, and the associated 5,000 tons of suint are wholly lost.

The possibility of utilizing waste wool itself as a chemical raw material should also be mentioned. A promising field of investigation is open here, as for example in the production of protein hydrolysates of special type for medicinal use, for fertilizers or for the manufacture of synthetic fibres and plastics.

2. FOREST PRODUCTS

Trees of the genus Eucalyptus are overwhelmingly predominant in the temperate forests of Australia and Tasmania. Although very greatly depleted by fire and alienation, these forests are still capable of yielding large amounts of products. Only three will be considered here—wood pulp, lignin and eucalyptus oil.

Wood pulp

Eucalypts are hardwood trees and yield a short-fibred pulp in contrast to the long-fibred coniferous pulps produced in other parts of the world. The difficulties associated with the use of short-fibred pulps for paper-making have now been overcome, and large quantities of paper are produced in Australia and Tasmania into which eucalyptus pulp enters largely or wholly. Four methods of pulping are used—

(*a*) Mechanical grinding and partial bleaching for the production of cheap newsprint. Owing to the demand for freedom from colour in the finished sheet, only the best and whitest wood is used for pulping at present.

(*b*) Cooking with caustic soda and bleaching, to produce soda pulps for printing, writing and blotting paper.

(*c*) Cooking with caustic soda and sodium sulphide (Kraft process), to produce pulps for wrapping-papers, cement-bags, etc., and bleaching and refining for special papers and high-alpha cellulose.

(*d*) Partial cooking with diminished concentrations of reagents to produce semi-chemical pulps for boards, etc.

Eucalyptus wood requires in general less alkali for pulping than softwoods because of the lower content and more reactive nature of the lignin in it. However, the pulp contains a larger amount of more resistant xylan than a softwood pulp, and for special purposes, such as the production of high-alpha cellulose pulp for explosives and the viscose industry, the content of this xylan must be reduced by special refining processes. The technique for this has been worked out in Australia, and conservative attachment to the use of long-fibred pulps should not hinder the development of short-fibred stock for these purposes, as vast quantities of short-fibred pulp are potentially available either as growing forests or fire-killed timber suitable for pulping.

Lignin

The lignin removed from wood during the chemical pulping process remains in the spent liquor and is usually burnt for the recovery of the alkali. In Victoria, some 10,000 tons of dry lignin could be obtained annually from these liquors, and about half this quantity in Tasmania. The Victorian material contains combined sulphur and the Tasmanian does not, while neither represents the true lignin originally present in the wood. The reason is that chemical pulping is a crude process in which the lignin of the wood may suffer a preliminary polymerization under the action of the alkali and then has to be degraded by further severe cooking into a soluble form which may be precipitated from the resulting ' black liquor ' by acid. During the cooking, the cellulose of the wood is partly degraded also, with consequent lowered yield of pulp, and the pulping process of the future aims at modification to minimize this disadvantage. The most promising methods seem to be hydrogenation of the wood in alkaline solution at high pressures, resulting in the production of alcohols and hydrocarbons from the lignin which can be used as fuel, and the process of preliminary acid hydrolysis of the wood followed by a mild alkaline cook. Australian hardwood may lend itself particularly well to the latter process, as it is capable of supplying its own acid for the hydrolysis, which yields a good tanning extract from the wood. Some work has been performed in this direction, but much remains to be done.

Eucalypt lignin is more reactive chemically than coniferous lignin, and work is in progress to define these chemical differences more clearly. The alkali recovery process as applied to ' black liquor ' does not depend on the combustion of its lignin for its success, since other fuels may be used if the lignin were extracted from it. Tests show that eucalypt lignin and thio-lignin may in future supply large amounts of thermo-setting and thermo-plastic materials for plastics and laminated products, either by themselves as extenders, or in combination with phenols, amines or aldehydes. There is also the possibility of useful organic intermediates being made from it.

Eucalyptus oils

These oils are distilled from the leaves of many species of eucalypts. Two general types are obtained—the cineol type and the phellandener type. Each type consists of complex mixtures of terpenes and related compounds, and only the cineol type is suitable for medicinal use. The

bulk of the oil produced in Australia is exported or used locally for mineral flotation. The oil is relatively easily obtained, as the spent leaves may be used as fuel for the steam distillation. No production figures are available, but immense quantities are potentially available in Australia and Tasmania.

3. STRAW AND AGRICULTURAL WASTES

A vast quantity of straw is potentially available from the annual Australian wheat crop. In Victoria alone this straw may amount in a normal year to one and a half million tons from a yield of about half a ton per acre. The difficulty of utilizing this material is mainly one of collection and transport. The crop is seasonal, from November to January, and the method of harvesting is generally by stripping, which separates the grain and leaves the straw standing in the field. After stock have been allowed to pick this over, the straw is either burnt to control fungal pests or is ploughed in. With an assured market it would be possible to harvest the straw as well, but up to the present the difficulty of obtaining a continuous supply of straw at sufficiently low cost has seriously handicapped industries which try to use it.

One use for straw is in the production of a semi-chemical pulp for the manufacture of strawboard by cooking under pressure with lime. Some 10,000 tons of straw are used annually for this purpose in Australia. Attempts have been made to combine this with furfural production, but the yield is insignificant for commercial purposes. On the other hand, acid hydrolysis of the straw may yield from 6 to 8 per cent of furfural, but the resulting pulp is so degraded as to be useless. The recent claims of some German workers that both furfural and pulp may be obtained in good yield by mild acid hydrolysis followed by alkaline cooking have been tested in Australia ; the yield of usable pulp was satisfactory but that of furfural disappointing, although the method may be capable of development.

Oat hulls, rice hulls, cotton-seed hulls and maize cobs have been shown to yield from 10 to 11 per cent of furfural by acid hydrolysis, leaving a residue which might be used as a filler for plastics. Some 15,000 tons of these materials are available annually in Australia. However, furfural comes into competition with formaldehyde for plastic manufacture, and the local production of formaldehyde is at present ample, while other uses for furfural such as in the rubber industry and for oil refining are negligible in Australia. Consequently the local market for furfural could hardly absorb more than from 100 to 500 tons annually for use in plastic manufacture where its special properties of increased flow in the mould, better bonding and higher heat-resistance than the phenol-formaldehyde resins, have an advantage.

Hardwood sawdust is another possible source of furfural, but the yield is poor and the residue is unsuitable as wood pulp. Immense quantities of sawdust and waste from logging and milling operations accumulate in forest areas in Australia, where they constitute a very serious fire risk and indeed are ultimately destroyed by fire. Large quantities of charcoal were made from waste wood during the war for use in automobile gas-producers by the simple and crude process of burning in a restricted supply

of air, whereby the valuable volatile products were lost. Proposals by the Victorian Forests Commission to establish this industry on a sound technical basis met with no response from the Government.

4. SUGAR-CANE PRODUCTS

Just before the war, Australia crushed annually more than 6 million tons of cane to produce nearly 930,000 tons of crude sugar and about 24 million gallons of molasses. These amounts have fallen during the war years, but they are still very large. Four products will be considered.

(*a*) Sugar as a chemical raw material

Most of the sugar produced in Australia is used as a food, or in the preparation of foodstuffs and in confectionery. The feasibility of using sugar directly as a chemical material has been studied in order to meet a predicted world over-production in the near future, and for obvious reasons the possibility of using the expressed cane juice instead of manufactured sugar commends itself. No published work on this matter has appeared in Australia, but American workers have been active for the last fifteen years, although no commercial process seems yet to be in operation on a large scale.

The general directions of this work have been the production of alkyl esters of laevulinic acid for use as solvents for gums and resins, of octa-esters from sugar as a polyhydric alcohol for adhesives, cooking with lime under pressure to make lactic acid, electrolysis of sugar solutions, the production of allyl sugar for use as a varnish, and hydrogenation of sugar, or of the sugar-cane itself, after treatment with alkali under pressure, to give chiefly hydrocarbon oils. The main use of sugar as raw material is, however, in the fermentation industries, where it is first hydrolized to hexoses and these are then fermented by a variety of organisms. This is considered in the next section.

(*b*) Molasses

The average composition of the 125,000 tons of molasses produced annually in Australia is

water	20 per cent
sucrose	36 ,,
reducing sugars	14 ,,
other organic matter	16 ,,
ash	14 ,,

About 50 per cent is sold to distillers for power alcohol and rum production, about 21 per cent is used as stock food, about 14 per cent as fertilizer, 13 per cent is burnt at the mills as fuel and a small portion runs to waste.

Controlled fermentation of molasses is capable of producing acetone, butyl alcohol, citric acid and lactic acid. Moreover, butylene glycol has been produced in Australia from wheat, and molasses may be used as the starting-point here. Butylene glycol finds application in the synthetic rubber industry. However, there does not appear to be much scope for the expanding use of Australian molasses in these directions, except in the

diversion of that which is now used as fuel. Large-scale development would seem to depend on the use of whole juice from sugar-cane, which means mechanical harvesting and the cultivation of large estates. The former is difficult to develop for a group of small farmers, and the latter is subject to much financial discouragement by the Queensland Government.

(*c*) Sugar-cane wax

This wax occurs in the cane and is precipitated in the mud which is removed during the clarification of sugar-cane juice. In this mud, there is about 1 ton of wax for every 1,000 tons of cane crushed, and a fair proportion of this may be removed by solvent extraction. There is a potential yield of some 3,000 tons of crude wax, or about 1,200 tons of refined wax, from 4 to 5 million tons of cane per annum. However, the mud is distributed among nearly two score mills and is difficult to transport as it contains about 70 per cent of water. The refined wax has a melting-point of about 73° C., but this is not high enough to enable it to take the place of the valuable carnauba wax (m.p. 84° C.), and the outlook is not promising.

(*d*) Bagasse

This is the fibrous material from the cane after the juice has been expressed. It is used as fuel in the mills and is more than sufficient for this need, so that large quantities may be accumulated. It is at present being used for the production of light wall-boards for constructional purposes and for the generation of electric power. It may also be possible to use it as a long-fibred pulp for mixing with short-fibred pulps from Australian hardwoods, but no chemical use of it has so far been made.

5. FELLMONGERY WASTES

Prior to 1939, about 20 million sheepskins were produced annually in Australia ; about half of this total was fellmongered in Australia, the remainder being exported, mainly to France. During the war, the annual production of skins has increased and so has the proportion fellmongered in Australia.

Fellmongery is concerned with the removal of wool from sheepskins. The skin removed from the slaughtered sheep includes portions extending over the head and legs ; the fellmonger removes these trimmings as they cannot be treated with the skins which are destined for leather after fellmongering. The trimmings, which may carry 15 to 20 per cent of the wool of the sheep, are processed to obtain this wool and are then suited only for making glue and gelatine.

Two methods of removing wool from the skins are used in Australia. The first is the sweating method, by hanging the moist skins in a closed chamber : natural bacterial action loosens the wool, which is recovered in excellent condition, but owing to difficulty in control the skin is liable to damage. The second method is by painting with a lime-sulphide mixture on the flesh side of the skin ; this digests the wool roots but causes no damage to the skin, although the wool tends to be made harsh. Most

countries have entirely abandoned the sweating method, but it is retained advantageously in Australia for fine-wooled merino skins.

Some fellmongered skins are so ribbed or wrinkled that satisfactory leather cannot be made from them. For these and for spoiled skins there has always been a ready local market (except in Western Australia) for conversion to glue and gelatine. In Western Australia the supply exceeds the demand, and the excess skins are buried as the easiest way of disposing of them. It might be possible to dry and grind these skins for fertilizer, or to dissolve them by enzyme hydrolysis as suggested for the trimmings.

The trimmings are treated in various ways. Painting with lime-sulphide is inadmissible owing to the cost of handling and the presence of flesh and fat, so that bacterial action in the main is employed by exposing the trimmings to partial putrefaction in air on the floor of the fellmongery, or in water. The wool is then picked out by hand and the skin pieces disposed of, if possible, for glue manufacture. Alternatively, the process is allowed to continue in solution until the skin is entirely destroyed, and the wool is then separated. Serious damage results to the wool, however, which becomes dark brown, and the effluent is very objectionable.

Recent work shows, however, that liquefaction of the skin can be made complete in twenty-four hours without damage to the wool by the action of hydrolytic enzymes extracted from mould grown on wheaten bran. The wool is easily separated, and the liquor is not offensive and might be incorporated in fertilizers. Other methods are known, e.g. digestion with papain, and a promising field of application is open here.

6. SEAWEEDS AND FISHERIES

Australian coastal and pelagic fisheries are not well developed. Even the local markets are relatively poorly supplied with edible fish, and no chemical industries of importance are based on the by-products of the fishing industry. However, processing of offal for manures and fodder has been established in some places, and the production of liver-oil rich in vitamin A from the snapper shark reached 15,000 gallons annually towards the close of the war. The full potentiality of Australian fisheries is unknown, but air surveys have given promising indications. It seems clear, however, that development and exploitation must proceed on lines rather different from those which have been successful in European waters.

During the war years, investigations were made in Australia on the production of agar from seaweeds, the Japanese supply being shut off. These investigations showed that a number of coastal seaweeds could be used for agar manufacture, and in particular *Gracilaria confervoides* from New South Wales waters might furnish a 50 per cent yield on the dried-weed basis. Problems associated with the industry are concerned with the seasonal growth of the weed, the difficulty of harvesting and the ability of the beds to withstand repeated cropping. The present output of agar in Australia is about 24 tons annually, but information on the supply of weed in extra-tropical waters suggests that at least 100 tons of agar can be produced annually from known sources. No proper survey of Australian tropical coastal waters has yet been made, although agar-bearing weed is known to occur near Cairns in latitude 17° S.

Agar has many uses, depending on the stability, high viscosity and hysteresis of its gel with water, and its stabilizing action in emulsions. Before the war, its main use in Australia was in food-packing and in confectionery, the scientific and medical uses being also very important but consuming only a relatively small amount of the material. Australian agar, unless decolorized by charcoal, is somewhat yellower than Japanese agar ; its setting-point is rather higher and its elasticity greater. The gel produced is more transparent with greater gel strength at higher concentrations and less at lower concentrations than the Japanese product, and it has lent itself admirably to meat-packing. Consumption of agar in Australia just prior to 1939 was some 70 tons annually.

There is also the possibility of establishing the manufacture of alginates in Australia, for large beds of the very suitable weed *Macrocystis* occur in Tasmanian waters and are relatively easily harvested in comparison with others used in the United Kingdom during the war. No information is available with regard to the quantities that might be available, but the remarkably interesting properties of the alginates and the varied uses to which they were put during the war make this a prospective industry with attractive features.

THE NATURAL PRODUCTS (BIOLOGICAL) OF NEW ZEALAND AND THE CHEMICAL INDUSTRIES THAT ARE OR MIGHT BE BASED ON THEM

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THE dependence of New Zealand's prosperity on her pastoral industry with its very limited range of exportable primary produce has been stressed by all students of her economy, and is dealt with in some detail in the first paper of this series. In any discussion therefore of her natural biological resources, the value of her sheep and cattle populations and of the pastures which support them completely overshadows that of any other product. It is natural also that in the desire to improve her primary industry and the secondary industries directly dependent on it, investigation has been almost entirely directed along the lines of increasing efficiency in these industries to the exclusion of work on products of less immediate or only potential value. This policy has unquestionably paid dividends in the past : its continuation in a world which has of necessity been forced to use substitute materials in the shape of synthetic fibres and margarine may not have the same effect.

It is necessary before discussing chemical industries centering round natural products to state one fact which must always be considered in discussing every industry in New Zealand. The cost of labour is high while the population and hence internal demand for any product is low. For any industry other than one designed to meet only internal demand and capable of insulation from the effect of world price levels, some especially favourable factor must operate in order that its product may compete in the world market. It may be in the cheapness and easy availability of the raw materials, in the high potency of the raw materials, in sheer technical efficiency or in a mixture of all these. But where the cost of labour represents a high proportion of the added value of the final product, the prospects of successful competition in the open market are not great.

This paper will deal first with those industries established in New Zealand which are directly connected with her primary industry in relation to existing or possible chemical industry ; and second with other natural products which are peculiar to New Zealand or which though not peculiar to New Zealand have potentialities for economic exploitation.

DAIRY INDUSTRY

Butter and cheese account for over 50 per cent of the value of New Zealand's total exports. Although the present efficiency of the processing industries is due in considerable measure to an increasing use of scientific,

and particularly chemical methods in manufacture and control of the final product, they can in no sense be termed chemical industries. Attention must therefore be directed to the by-products of butter and cheese manufacture, viz. skim milk and whey, and their utilization for special purposes. In this regard the seasonal nature of milk production must be emphasized since no manufacturing process based on milk can have continuity of supply of raw material.

(*a*) *Dried skim milk*—Not more than 5 per cent of the total skim milk produced in New Zealand is dried, the remainder being fed almost entirely to pigs. The efficiency of conversion of milk solids into pig flesh is low and the difference between milk ingested and meat produced is greater, in terms of protein alone, than New Zealand's total export of lamb and cheese. The problem, which is dealt with in the first paper in this series, is largely an economic one and is mentioned here to emphasize that an enormous waste of high grade protein occurs. The technical problems are connected with marketing in areas of low purchasing power, with the best methods of addition to the protein-poor diets of such areas, and with methods of dehydration and storage which will allow of entirely satisfactory re-constitution.

(*b*) *Dried whey*—The losses in whey are considerably less than those of skim milk, but again uneconomic utilization leads to a large overall loss of high grade protein.

(*c*) *Lactose*—The production of lactose in New Zealand has continued with some vicissitudes for over 30 years, the present prospects being at least as bright as at any time in the history of the industry. The world market for lactose, largely due to the demand of penicillin manufacturers, has expanded markedly during the past 3 years. Assuming a yield of 10,000 units of penicillin per 3 g. of lactose, a production of 600,000 million units per month involves a lactose consumption of over 2000 tons anually, a figure which is to be compared with an estimated total pre-war production of a little over 4000 tons.

The New Zealand process, which consists in evaporating whole whey under conditions causing a minimum of protein change followed by direct crystallization of the lactose, is technically efficient and the processing plants are favourably situated for the collection of the raw material. As a result it more than holds its own in the world markets. A considerable extension of the present facilities is already under way and the 1945 production figure of just over 1000 tons will be greatly increased. It is noteworthy, however, that 1000 tons of lactose is produced by only a small fraction of the country's whey production.

The concentrated mother liquor containing the soluble milk proteins, some lactose, lactic acid, mineral salts and accessory substances such as riboflavin is disposed of almost entirely as stock food. Although a considerable amount of work has been done towards a more economic utilization, nothing really promising has emerged. The recovery of lactic acid either as calcium lactate for export or as free acid for the internal market is technically practicable ; the problem is primarily an economic one. A relatively large quantity of orotic acid has been produced by pilot scale process but no market has been found to date. The commercial synthesis of riboflavin has made its separation from whey mother liquor uneconomic.

The conversion of globular into fibrous proteins, as has been accomplished with egg albumin by workers at the Western Regional Laboratories of the U.S. Department of Agriculture, is still a long way from providing a competitor in the field of synthetic fibres. If however success is attained, investigation of the soluble whey proteins as they exist in the mother liquor would be warranted.

(*d*) *Casein*—Casein has been manufactured by the acid process for some years, being precipitated from skim milk by the lactic acid produced by fermentation of lactose. No rennet casein is produced. The process is technically efficient and during the war years the demand has been much greater than the supply which last year amounted to just over 1000 tons. About 75 per cent of the output was exported. Production is strictly controlled due to the demand for pig meat by the United Kingdom and the consequent necessity for the retention by the farmer of nearly all his skim milk.

The post-war outlook is reasonably good although there is a constant threat from synthetic resins and plastics. Casein is likely to hold its own as an adhesive particularly for laminated plywood, there is a small but increasing internal demand from paint manufacturers while there is a field for some expansion in casein plastics.

The successful utilization of casein whey presents practically the same problem as is presented by cheese whey. It is used at present as pig food, and the efficiency of utilization is low.

MEAT INDUSTRY

The by-products of the meat industry play a major role in its economy, and their utilization by any factory makes all the difference between profit and loss. Those by-products which are of interest in this discussion are considered below.

(*a*) *Rennet*—Production of rennet started in 1918 and the industry is firmly established. It produces sufficient rennet to cover New Zealand's total requirements at a price considerably below world prices, and it appears that a profitable export market could be developed. The future of the industry depends on the cheese industry as the market for its products, and on the bobby calf industry which supplies the raw material. Both are flourishing and the prospects in the post-war period are encouraging.

(*b*) *Leather and hides*—By far the greater part of the skins produced in New Zealand are exported as such. The balance remaining in the country forms the basis of the tanning industry and is the source of practically all the leather goods sold in New Zealand. The industry suffers from the disability that with the exception of lime all the materials required in fellmongering and tanning have to be imported. Export of finished and semi-finished products represents a tiny proportion of production, and current economic policy furnishes the industry with an assured internal market.

(*c*) *Gelatin*—A sound industry is operating and there are apparently few technical difficulties. The supply of raw materials is of course excellent.

(*d*) *Glandular products*—On numerous occasions the utilization of endocrine glands, particularly the pancreas and the pituitary, for the

preparation of hormones has been suggested, but no factory has set up a plant for this purpose. The difficulty of dissecting out the glands is obviously not the major problem since considerable quantities of whole glands are shipped in the frozen state to England for processing. It is certain that even under these conditions major losses of potency occur and a strong case can be made for the processing of the glands here. At present assay presents a problem since no laboratory in New Zealand has the facilities for routine biological testing of hormone preparations. Less important are the relative smallness of factories and their distances apart.

The situation is by no means clear, but preliminary work that was done under the stimulus of war conditions indicates that particularly for the pituitary, a much fuller investigation is entirely justified.

(*e*) *Blood fractions*—The intensive effort which was expended on the fractionation of human blood during the war has resulted in a great increase in our knowledge of the various constituents of the plasma. Although American work indicates that no protein fraction can be safely used for transfusion purposes, there can be no doubt that our increase in knowledge of blood chemistry will be utilized along other than therapeutic lines. The more economic use of blood than its conversion into fertilizer is obviously a major piece of investigation but it is one in which New Zealand, with an estimated production of over 8 million pounds of blood solids, is particularly interested.

WOOL INDUSTRY

Since the whole question of fibres of animal and vegetable origin is considered in a paper for the evening discussions the topic is introduced for record. The possibility of degrading and re-spinning low grade and waste wool into a uniform product of higher quality will doubtless receive the attention it deserves.

Wool wax—The disposal of wool wax is one of the most troublesome problems facing woollen manufactures, and although the problem is greater for Great Britain, Australia and South Africa than it is for New Zealand a solution is urgently required here also. Little systematic work has been done on the problem, but a profitable outlet for the $3\frac{1}{2}$ million pounds of wool wax produced in this country would make such an investigation desirable.

MARINE PRODUCTS

(*a*) *Fish liver oil*—It is doubtful if the present flourishing industry would have been developed but for the war and the acute world shortage of vitamin A. A preliminary investigation dating from 1934 and utilizing livers from the fishing industry showed that certain of our larger edible fish gave oils of high vitamin A potency. A small industry based on the normal fishing industry produced some oil for export up till 1938, when a falling price level caused its disappearance. By 1940 however it had been established that there exist in the waters round New Zealand relatively large numbers of sharks and game fish with consistently high oil yields and vitamin A potencies. During the past three years a highly

successful industry has been established with two independent firms operating in Auckland and Wellington respectively. The Wellington factory draws its supplies largely from the fishing fleets, while the Auckland one processes livers from school sharks (*Galeorhinus australis*), some of which are obtained incidentally from the ordinary fishing fleet but with the majority coming from vessels chartered for the purpose. Present annual production for both factories is in excess of 25,000 gallons with an average potency for the Auckland factory of 30,000 I.U. per gram. It is estimated that present production is equivalent to over 500,000 gallons of cod liver oil.

Another almost untapped source of even higher potencies is the so-called swordfish (*Makaira* spp.) which exists in large numbers off the northern coast. Values of 320,000 I.U. per gram have been obtained and make swordfishing a potentially valuable industry.

Even on conservative estimates the industry is in a flourishing condition and the present capacity is little more than enough to cover export contracts for the next five years. It appears to be well equipped to compete on the world markets with oil from any other source under peace-time conditions.

Research is required along two main lines—biological and chemical. Comparatively little is known of the ecology of the fishes mentioned and a rational conservation policy based on such a study is obviously required. At the moment the raw materials are in good supply but this situation could easily change if reckless utilization methods are practised. Considerable chemical investigation on the distribution and form of vitamin A within the liver is desirable in order to increase the efficiency of extraction. The preparation of concentrates by molecular distillation would ensure that full advantage could be taken of the sharp price gradients per unit of vitamin for oils of increasing potency.

(*b*) *Agar*—In common with other countries New Zealand found herself cut off in 1941 from her supplies of agar for both bacteriological work and for certain canning processes. In anticipation of this a survey of red seaweeds was made during the period 1939–41 and it was found that there exist extensive fields of easily accessible material, largely *Pterocladia lucida*, which gives satisfactory yields of high quality agar. Commercial production was undertaken by a firm engaged in gelatin manufacture and the industry is well established. Collection is done almost entirely by Maoris who are paid a flat rate of 1s. per lb. of dried weed and has proved a considerable source of income for coastal communities in the North Island. In 1943, the first fully operational year, collections of dry weed amounted to 73 tons.

The future of the industry is not so clear cut as is that for fish liver oil, but is fairly bright. The war-time price of 25s. per lb. is five times that of pre-war Japanese agar but against that must be considered the higher gel. strength, easier handling and superior clarity of the New Zealand product. Much will depend on the rate of regeneration of the Japanese industry and the premium which is offered for quality. Raw materials are in good supply, collection is a relatively easy matter and the rate of regeneration of the weed is quite satisfactory.

(*c*) *Alginic acid*—Alginic acid as a valuable addition to the range of

synthetic fibres has attracted considerable attention during the war years. A recent survey of *Macrocystis* on the New Zealand coasts shows that an annual harvest of about 4000 tons of dry kelp from Cook Strait area alone at an estimated cost of £10 per ton may be reasonably achieved. No exploratory work has been done on processing, but the potentialities of alginic acid are so great that a considerable effort in this direction appears justified.

(*d*) *The whaling industry*—The New Zealand whaling industry based on Cook Strait is but a shadow of its former self, but it may be assumed that the extensive industry based on Sub-Antarctica will be resumed after the war. The companies now operating are interested primarily in oil, but some investigation of other by-products particularly the endocrine glands, is considered justifiable.

OTHER NATURAL PRODUCTS

(*a*) *Forest products*—The more economic utilization of timber has been exercising the timber producing countries of the world for many years. It is a problem of considerable importance to New Zealand since she is particularly well equipped by climate and soil for the rapid growth of a variety of timber trees. Her exotic forests now total over a million acres and can be greatly extended on land which is sub-marginal with respect to her pastoral industry. Pulping of these forests has begun on a big scale and the industry, partly because of favourable conditions during the past six years, is well established. It is considered that if the by-products of the timber and pulping industries could be efficiently utilized the possibility would exist for a much needed diversification of our production with a consequent increase in our economic stability. The problem is a technical one and it is important enough to justify considerable expenditures on research work, both for a research unit within New Zealand and in co-operation with other timber producing and timber processing countries.

(*b*) *Phormium industry*—The New Zealand flax, *Phormium tenax*, is practically the only indigenous plant on which an industry has been based, but its history is a chequered one. Phormium fibre has to compete in the world market with the similar type fibres, manila and sisal, for cordage manufacture, and its competitors have the advantage of cheap labour and better organization. Investigations of the plant and of its fibre have been sporadic and no systematic or concentrated attack on the chemical phases of the problem has been made. In view of the natural advantages possessed by the plant in high fibre yield per acre and per unit of green weight of the leaf, such an investigation is fully warranted. Taken in conjunction with the breeding and selection work which is now well established the phormium industry could become a valuable asset.

Utilization of phormium fibre for the rayon industry does not appear practicable but it can be used for the manufacture of high grade paper. Here again the problem is largely one of economics.

(*c*) *Nicotine*—Insufficient tobacco is grown in New Zealand to supply her needs, but even this small industry provides enough waste material to make the separation of nicotine an economic process. The technical difficulties have been largely overcome and there seems no reason why

about half of New Zealand's requirement of nicotine should not be obtained from locally grown tobacco.

(*d*) *Medicinal plants*—During the war small areas of *Digitalis purpurea*, *Datura Stramonium*, *Belladonna* and *Hyoscyamus* were grown for the internal market, and the venture was successful both in making up the internal deficit and in supplying the English market. Leaf of excellent quality was obtained and preliminary experiments in breeding and selection indicated that considerable improvements in strain could be accomplished, while processing of the leaf presented no major difficulties. The peace-time success of the industry would depend on its ability to compete on the world market, since the internal demand would probably not support an economic unit. The situation therefore resembles that of the agar industry with the exception that plant breeding methods could be used with effect. It is considered that an investigation leading to an accurate estimation of cost of finished product would be justified, since inquiries about further supplies of New Zealand leaf have been received from both English and Australian firms.

NATURAL PRODUCTS OF THE EMPIRE AND THEIR UTILIZATION

By Dr J. L. Simonsen, F.R.S.

The field covered by this title is so vast that it is possible only to give a brief survey within a reasonable space. The main object of this note is to promote discussion, and it would savour of impertinence were I to attempt to cover the subject in so far as it concerns the Dominions and India whose representatives at the conference are far more competent to deal with their own problems.

It is, however, hardly necessary to point out that if the natural resources of the Empire are to be fully utilized it can only be achieved by the closest collaboration of its members. There must be a rapid interchange not only of information but also of workers. This has been largely lacking in the past, and many have suffered from scientific isolation with resulting los sin efficiency. The necessity for this collaboration is obvious if we recognize the similarity of the many problems with which we are faced. Geography does not recognize political boundaries.

It is frequently thought that the far-flung British Empire and Commonwealth has resulted from the exertions of traders and adventurers, but this is far from being the case. Its origins have been diverse, and men of science have in the past played a not inconsiderable part. I would refer to the contributions of Fellows of the Royal Society, such as Captain Cook, Sir Joseph Banks and to the initiative of the directors of Kew whose far-sighted efforts have played so important a part in its economy.

The natural products of the Empire may be divided roughly into two classes—mineral (wasting) and agricultural and forests (growing) assets, but the deciding factor for their utilization is in all cases *water*. Upon water all development depends, a fact which in the past has far too frequently been ignored. Upon an adequate supply of this, man, stock and crop depend, and since in the greater part of the Empire fuel (oil and coal) is somewhat limited, hydroelectric power, when suitably sited, may economically supply both heat and power. I would suggest, therefore, that much more attention be given to a survey of the Empire water resources for whatever purposes they may be required. This is a function of geologists and engineers, and it is satisfactory to note that this important aspect of future industrial development has been so fully recognized in the Indian Empire, already a leader in the study of the problems of irrigation.

There are two factors which lie outside the scope of this note, but which are bound to have a decisive effect on the future of the Empire—disease and nutrition. The recent great advances in chemotherapy and in the uses of synthetic insecticides are likely to revolutionize life in the tropics and in themselves facilitate the raising of the standard of living of the indigenous people.

Mineral Resources

In spite of the fact that the geological survey of the Empire, and more especially is this true of the Colonies, is still very inadequate, it is known that the Empire is exceptionally rich in minerals of economic importance. It is hoped that the extensive topographical and geological surveys now being organized will bear rich fruit.

No useful purpose would be served by listing the mineral resources of the Empire or by discussing their industrial utilization. In the Dominions and India the ores are largely processed, I would refer only to the large Canadian aluminium and nickel industries, the iron and steel works in Australia and India and the gold in South Africa, but, in the past, the processing of ores in the Colonies has been somewhat limited. The time has now probably arrived for the bauxite deposits of the Gold Coast and British Guiana to be converted into aluminium ingots in the Colonies. If the possibility of adequate water power being available in each of these Colonies can be established, this should prove a far more economic proposition than the export of the ore. The development of such an industry would provide occupation for some of the future graduates of the West Indian and African universities and make demands also upon the skilled labour of the indigenous population. Local use, as for example, in a glass industry might also be found for the rich sands of British Guiana. While such developments as these do not require research but only the application of well-known methods, there is little doubt that they would lead to the establishment of subsidiary industries based upon research. I would suggest, for example, that a fruitful field may lie in the prospecting for new sources of low-grade ores and in the investigation of new and improved methods for their utilization. The rich ores of some metals, such as lead and tin, are rapidly becoming exhausted, and it is clearly becoming essential to process much lower-grade ores.

Unfortunately the Empire is not rich in mineral oil deposits, the main sources at present being the Punjab and Assam in India, Burma, Borneo and Trinidad. It would appear to be not improbable that another source may be found in Barbados. This has still to be proved. The discovery of oil in Barbados would be of great importance in view of its rapidly increasing population which has at present to depend solely on agriculture for its livelihood. In none of the Empire oil-fields have any steps as yet been taken to develop a chemical industry based upon either the natural gas, the refinery gases or upon the oils themselves. Admittedly the isolation of some of the fields, such as that in Trinidad, affords difficulties but these should not be insuperable, and it is to be anticipated that such developments will take place in the future.

Agriculture and Forestry

Agriculture is the main industry of the Empire and it is essential, therefore, that it should be carried out with the highest degree of efficiency, and that for the solution of its many problems the full resources of science should be made available. In many respects the agricultural problems of the Empire are the same since so much of it lies within the tropics or semi-tropics, and it thus provides a field for the closest collaboration. Within

the Dominions agriculture is undoubtedly carried out with great efficiency, but the same is not true for India and for many of the Colonies. Here in many cases the methods are still primitive. For a successful and efficient system we require a detailed knowledge of the soil, based on adequate soil and soil-fertility surveys combined with a study of ecology, plant and animal breeding and the prevention of plant and animal disease. Even when the scientific background has been provided its application will require the education of the cultivator. Of great importance also for the maintenance of prosperity is a correct balance between food and cash crops.

The rapid development of synthetic organic chemistry is likely to exercise an influence on the future of agriculture since some of the more valuable products of the soil, direct or indirect, are being replaced by synthetic products derived from oil and coal. The first serious impact of the laboratory was probably the replacement of the common madder root, *Rubia tinctorium*, by alizarin, but the most sensational advance was undoubtedly the manufacture of synthetic indigo which signed the death-warrant of the Indian and Javan indigo plantations. Unfortunately for certain aspects of agriculture the synthetic chemical industry has not stood still. It would appear not improbable that ethylene will replace molasses as a source of industrial alcohol and that many of the products previously obtainable for agricultural waste products may be manufactured from acetylene. It is perhaps hardly necessary to refer to the great advances made in the field of plastics, the replacement of the products of the cinchona bark by mepacrine and paludrine or the synthetic analgesics which have largely replaced cocaine and may replace morphine.

Parallel with these developments will be seen an increased use by the chemical industry of agricultural products, as for example the synthetic fibres based on cellulose and the proteins of oil seeds ; the synthetic plastics from furfural and rosin and the uses of the various constituents of essential oils in organic syntheses. It is indeed by the increasing utilization of agricultural raw materials and wastes that advance must be sought. The products available in the largest amounts are the vegetable oils, cellulose, sucrose and starch. Of cellulose increasing use is being made, but although sucrose is the purest organic chemical manufactured on a large scale, it has, apart from its uses for nutrition and in the fermentation industries (see below), found comparatively little industrial application. This is doubtless due to its molecular complexity. The desirability of intensive research to find new uses for sucrose has in recent years been clearly recognized both in this country and the U.S.A. Results of considerable promise have already been obtained by the Birmingham school.

Doubtless also there is considerable scope for the introduction of improved methods in the treatment of the cane. This aspect can best be studied by a sugar research association in the West Indies working in close collaboration with research laboratories in South Africa, Queensland and the Dutch East Indies. It seems clear also that close contact should be maintained with the activities of the Beet Sugar Research Association in this country.

Important as these new openings for the utilization of sucrose may prove to be, it must of course be clearly recognized that results of equal if not greater economic value can accrue from an improved yield of cane resulting

from either the introduction of improved varieties or from better cultivation. Of fundamental importance in the cultivation of the sugar-cane are plant breeding stations such as those in Barbados and India.

Research into the utilization of bagasse other than in the manufacture of furfural or wall board will also require to be undertaken, but clearly the subject is one of considerable difficulty.

Although starch finds already a very extensive application in industry, recent research resulting in the facile separation of its two constituents—amylose and amylopectin—would appear to suggest the prospect of new technical uses. It is now essential to re-examine the main starch-yielding plants to determine in how far they differ in the character of their starches. An indication that such a survey may prove profitable is furnished by the differences which have already been observed (Hirst *et al.*, *Nature*, 1945, **156**, 786). Very little is known as to the technical possibilities of the various 'yams.' These have up to the present only been used as foodstuffs.

The most ancient technical use of carbohydrates has been in the fermentation industries, and these will continue to be the most lucrative since we have on the one hand the manufacture of beverages, such as rum and gin, and on the other industrial alcohol. Although the manufacture of industrial alcohol is undertaken in the Dominions and in India, in the Colonies, apart from Mauritius where alcohol is used as a fuel in internal combustion engines, manufacture has been on a very limited scale. The recent change in the excise law in this country should stimulate manufacture in the sugar-growing Colonies, and encouragement would be given to this much desired development if the use of a certain percentage of alcohol in the fuel for internal combustion engines were made compulsory in these Colonies. It seems certain that a greater economy and efficiency in the use of molasses will be necessary if alcohol from this source is to compete with that manufactured from ethylene. Of lesser, although of considerable, importance are other fermentation industries based on molasses, namely, the manufacture of solvents such as acetone and butyl alcohol and the acids, citric, lactic, gluconic, itaconic and fumaric. Whilst the demands for gluconic acid are not likely to be large, citric and lactic acids are already manufactured on a considerable scale, and uses are likely to be found in the plastics industry for itaconic and fumaric acids.

In view of the possible diminished demand for molasses as a source of industrial alcohol, it is essential to search for other uses for this valuable raw material. One such has been found already in the manufacture of food yeast, a valuable protein foodstuff. Since it is essential to improve the quality of the cattle in both the Caribbean and the African colonies where protein foodstuffs are limited, it might prove profitable to investigate the possibility of the manufacture of a cheap yeast cattle food. Mention may be made also of two further uses for molasses, namely, the production of enzymes of technical importance, such as invertase, and its more novel use in the manufacture of antibiotics. It is certain that we are on the threshold of new and important discoveries. It is clear, therefore, that here microbiological research offers unique opportunities, and this has been recognized by the decision to open a colonial microbiological research institute in Trinidad which will be under the direction of Dr. A. C. Thaysen.

Of almost equal importance to the carbohydrates are the oil seeds of the

Empire, including as they do copra, the palm, groundnut, linseed and castor oils. It has in the past been the custom for most of these oils to be processed not in the country of origin but in the more highly industrialized countries. It is doubtful if this is economically sound since if the oils were extracted in the country of origin the cake could be used in maintaining and restoring the productivity of the already impoverished soils and to provide foodstuffs for the stock. It is desirable also that an economic use should be found for the shells and other waste products of the industry. Implementation of some of these suggestions may involve administrative difficulties with which we are not here concerned. Increased attention should be paid also to the lesser known oils and fats, for should any of these prove to be of industrial value they could doubtless be cultivated.

On many estates in the Colonies the cultivation of plants yielding essential oils has met with success, but the markets for such oils are comparatively limited. It is unfortunate that only in India and Burma are there large stands of *coniferæ*, and these are in part very inaccessible. They provide the only Empire resources of oil of turpentine and of rosin, both of which are finding increasing industrial uses, more especially in the plastics field. It might be advantageous to determine whether afforestation with *coniferæ*, such as *Pinus maritima* or *P. excelsa*, in some suitable areas within the Dominions or Colonies would not be successful. The most extensive essential oil industry within the Empire is based upon the *eucalypts* of Australia. This provides an admirable example of the value of fundamental scientific research since it owes its success mainly to the classical work of Baker and Smith, so admirably continued by Penfold. The synthetic chemical industry has also had its effect on the cultivation of plants yielding essential oils. Thus the manufacture of vanillin from lignin or guaiacol endangers the clove-stem oil industry so vital to Zanzibar and the cinnamon-leaf oil of the Seychelles. The commercial value of both these oils depends upon their eugenol content, and they are used mainly in the manufacture of vanillin. It seems certain that these two oils will only continue to be used for this purpose if they can be sold at a reasonably low price since the American market for them has already been lost. It is clearly urgently necessary therefore that new uses for eugenol should be found.

Attention is suitably directed here to two further minor forest products, namely, lac and the oil from the seeds of *Anacardium occidentale*. It might prove profitable to introduce into the Colonies the cultivation of lac, whilst for the oil from the seeds of *A. occidentale* the plastics industry is already making heavy demands. This latter plant might well receive more extensive cultivation in East Africa and in Zanzibar.

The Empire provides the larger part of the world's supply of rubber, wool, jute, lac, tea and cocoa, whilst large areas are devoted also to the cultivation of cotton, sisal, coffee and tobacco. The importance of fundamental research for the future of all these products has been fully recognized and is in most cases supported by a cess on the raw material. It is realized that the future of the natural rubber industry is insecure and that this will to a considerable extent rest upon the cost of production. A low-priced material must depend upon the introduction of high-yielding trees and upon the fullest utilization of the by-products of the industry, such as the rubber seed, which, as Hilditch has already shown, yields an oil of economic

value. The cocoa research stations at Tafo (Gold Coast) and at the Imperial College of Tropical Agriculture (Trinidad) are faced with problems of a different character, namely, the problems of disease. The diseases affecting this crop are such as to greatly endanger its future, and it will require research of the highest order if they are to be successfully combated. It may be suggested that if greater attention had been paid in the past to the question of soil fertility the tree might have been more resistant to disease.

Reference should be made also to the increased interest which is being shown within the Colonial Empire to the cultivation of fruits such as citrus in Palestine and Jamaica and other islands of the Caribbean. Successful and economic marketing of these will depend upon the fullest utilization of the by-products—essential oils, pectins, etc. This has already been clearly recognized in South Africa, and continued research in these fields will be necessary. Of growing importance, more especially to South Africa and Australia and to a lesser extent Cyprus, is the wine industry. Here science has an increasingly important part to play.

Finally, attention may be directed also to other natural products which may be regarded as of minor importance, namely, gums and plants of potential medicinal and insecticidal value. For East Africa the cultivation of pyrethrum is of considerable importance, and it would at present not appear improbable that the introduction of the new synthetic insecticides is likely to increase rather than to diminish its use. On the other hand there seems likely to be a lesser demand for derris. The great advances in chemotherapy have resulted in a diminished interest in drugs derived from plants, but these are still worthy of further study.

If we except the production of hides, the improvement in the quality of which owes so much to the advice of the Hides Advisory Committee of the Imperial Institute, in the Colonial Empire too little attention has been paid in the past to the possibility of industries based on livestock and fish. The success which has been achieved in the cultivation of fish in Palestine and elsewhere indicates that, in addition to the study of sea and inland fisheries, research on fish may yield results in unexpected directions. This is clearly a field in which close co-operation should prove most fruitful.

Intensive research of a high order will be required if the rich Empire resources are to be fully utilized. First things must come first. Opinions here will naturally differ, but the writer would suggest as the most important, geological and soil surveys, plant breeding and carbohydrate research.

Whilst much has been omitted it is hoped that the ground covered in this note has been sufficiently wide to indicate the resources of the Empire and to stimulate a discussion as to how these resources may best be utilized.

MORNING SUBJECT (m)

POST-WAR NEEDS OF FUNDAMENTAL RESEARCH

Steering Group

Chairman—Sir David Rivett, F.R.S.

Recorder—Professor P. M. S. Blackett, F.R.S.

Sir Shanti Bhatnagar, F.R.S.
Sir Alfred Egerton, Sec. R.S.
Dr J. C. Hopkins
Professor W. A. E. Karunaratne
Dr C. J. Mackenzie
Dr E. Marsden, F.R.S.
Sir Edward Salisbury, Sec. R.S.
Professor B. F. J. Schonland, F.R.S.

Report

As a basis for this discussion the delegates had before them the report of the Royal Society on the Post-war Needs of Fundamental Research which attempts to analyse and measure the needs for fundamental research of the United Kingdom. This report and the discussion itself emphasized the need for more concrete guidance of the future development of fundamental science. Steps for the improvement of such guidance were considered.

Of primary importance was the question of making available adequate financial resources and of guiding them into fertile channels. To be effective, any measures to these ends must also comprise others designed greatly to increase the supply of scientists themselves. The Barlow Report on scientific manpower recommended the doubling of the output of scientists from the universities in the U.K. within ten years and gave evidence that this could be achieved without any reduction in standards of quality.

The question of secrecy in university work was discussed, especially in connexion with research work undertaken by universities for public authorities and for industry. Such secrecy was deprecated and the Conference was agreed that in principle it should be avoided.

Delegates from the Dominions and Colonies emphasized the need for work in special fields in their own countries. In several parts of the Commonwealth, not including the United Kingdom, it was felt that biology was neglected. In the Commonwealth generally there is a great need for more taxonomy in regard to plants and animals for without accurate identification efficient exploitation is impossible for increased study of genetics and microbiology. The importance of microbiology in relation to other subjects, in particular the geology of oils, coal, etc., and to industrial processes, was emphasized.

Delegates expressed the view that at present large scale plans for agricultural development had to be undertaken without an adequate scientific background. As pre-requisites for administrative action, taxonomic researches for plant and animal breeding were much needed especially in parts of the Colonial Empire.

The discussion ranged over a number of topics, including the burden of teaching, which effectively prevented research in universities where

insufficient staff was provided. The recent growth of appreciation of pure science in India, had resulted in many scientists leaving the universities for administrative posts and the funds available for scientific work in the universities were not sufficient to prevent this tendency. A discussion took place on the desirability of diverting physicists, after graduating, into biological and medical subjects. The central position that genetics was taking in the biological field was strongly emphasized and it was urged that special steps should be taken to remedy the somewhat backward condition of this subject in the United Kingdom and in the Empire, both as regards research and as regards its incorporation in biological teaching.

General statement

The Conference wishes to draw the attention of all concerned with the guidance of fundamental scientific research to the Royal Society's 'Report on the Needs of Research in Fundamental Science after the War.' It would also call attention to the report on Scientific Manpower recently issued by the Government of the United Kingdom.

The discussion at the Conference, which was of necessity limited in scope, revealed a particular shortage in the Commonwealth of scientists in such fields as taxonomy, genetics and microbiology.

Recommendations

1. The Conference is of the opinion that in each country of the Commonwealth the mechanism for guiding long-term research in fundamental science should be reviewed, in order to foster fertile research work in all important subjects. The systems for advice and financial assistance in this connexion should be studied carefully.
2. The needs of the future will require a great increase in the number of scientists and it is considered important that plans for extending fundamental research in any field should be supported by measures designed to increase the number of trained scientists able to carry out such plans.
3. In order to secure the proper flow of young scientists from educational establishments, it is considered of importance that the educational system of each country should be harnessed so far as may be necessary to this particular long-term need.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr F. M. Burnet

Microbiology developed largely as an offshoot from medicine and to date its greatest practical achievements have been in the field of infectious disease. There is no danger of interest in that field waning, but future developments will probably be in other directions notably :

1. The use of micro-organisms for the study of the relation between genetic determinants and the fundamental biochemical processes in the living cell. Beadles' work along these lines with neurospona has provided a technique for a more basic approach to an almost unlimited range of such problems.
2. Food production by micro-organisms. Organisms such as yeasts and bacteria are the most efficient producers of protein from simple C and N sources, as well as providing high concentrations of B-complex vitamins. Intensive basic and technological research may provide economically important sources of human food especially for tropical peoples and of protein supplements for domestic animals, e.g. pigs and poultry.
3. Microbiological processes in geology. The formation of oil, coal and certain types of iron ore have depended in part on microbiological action. Weathering of rocks, soil formation, and various aspects of corrosion in stone and concrete structures are also related to such action and a wide range of research in the field is required.

Professor J. S. Foster

In thanking those who brought about this discussion, I should like to pay a special tribute to the memory of Professor R. H. Fowler, F.R.S., who was greatly beloved by Candian scientists.

As is well known, fundamental research in Canada has from time to time already reached a very high level in ' certain sciences.' This growth naturally began in the universities and has gradually extended to laboratories of government departments, to a few research institutes and to the new laboratories of the National Research Council.

We urgently need financial help to relieve certain members of university staffs from excessive teaching duties. It is hoped that committees will be set up to advise the provincial governments which under existing law must take action on matters of general education.

While young scientists have profited greatly from scholarships and aids received through the National Research Council and other bodies, we need

to extend this assistance in general and in particular to young men who seem likely to become masters of some phase of science. Sustained support of the latter type is needed in a great variety of fields.

There is much opportunity for fundamental research to assist industries which have got into trouble, and the results of such investigations receive immediate application. Without modifying our attitude towards such effective research, it is even more attractive to open up new industries by breaking down fundamental barriers which appear to lie between our natural resources and the needs of the people.

Professor E. J. HARTUNG

Fundamental research in Australia is prosecuted in the universities and in research institutions of the type of the Walter and Eliza Hall Research Institute attached to the Royal Melbourne Hospital. It is also carried on to some extent in the laboratories of the Council for Scientific and Industrial Research in order to provide the necessary stimulus in inducing really good men to remain on the staff. In the universities, the maintenance of strong research schools depends on building up teams of postgraduate research students backed up by an effective body of more senior men. In inducing students to remain for a time in university laboratories to do postgraduate research, the universities come into strong competition with industry and with the C.S.I.R. Present research grants are inadequate to meet this competition and urgently need amplification ; in addition the Ph.D. degree has been established in Melbourne as a further inducement and to make exchange of postgraduate workers between Australia and other universities possible.

The great pressure of elementary teaching which the training of ex-service men and women has forced on the universities is tending to displace the main university effort away from research work and is very discouraging to the staff. One way of ameliorating this discouragement would be to increase the senior teaching staff so that each member of it could expect to have at least one year in every three or four years free from teaching duties, which he could devote entirely to his researches, either in his own or another university.

Professor E. SHERBON HILLS

Without wishing to raise again the question of whether or to what extent geological mapping may be regarded as fundamental research, I do want to point out that while sound mapping is basic to all geological work, and to this extent is fundamental, not all mapping is carried out in that spirit of inquiry which is essential if the work is not to degenerate into routine investigation which may indeed be of doubtful reliability. The terms of employment of many field geologists in Australian surveys do not afford these men adequate opportunity to develop new and original conceptions based on their own field work, because they are expected to spend too great a proportion of their time in the field. Such conditions have a restricting effect on the field geologists themselves and also tend to deter young and enthusiastic recruits who are imbued with the research idea from seeking employment as field geologists.

Geology is in great need of further precise data on the physics and chemistry of rocks and minerals, much of which must be derived from studies on the geological border-sciences. Geophysics is now well established, but geochemistry has not been sufficiently developed within the British Commonwealth ; experimental studies may be expected to yield data regarding the origin of rocks and ore bodies which will greatly assist in the search for economic minerals ; regional studies of trace-element distribution have already been used in North America in the recognition of mineral provinces, and the principles of mineral chemistry also find important applications in process-metallurgy. Dr Burnet has referred to the applications of micro-biology in geology and I should like to support his remarks. Research is required on the micro-biological aspects of peat and coal formation, of the formation of mineral oil and the composition of underground waters, and of mineral deposits such as bog iron-ore and bauxite ; also on the possibility of utilizing micro-organisms for beneficiation of such ores, a subject to which some attention has been given by C.S.I.R. officers in Melbourne. One may also refer to the field of biogeochemistry which is of particular interest in connexion with the occurrence of trace-elements in rocks, of micro-nutrients in the resulting soils, and finally of concentrations of trace-elements in plant and animal tissues, which may subsequently become constituents of coal, mineral oil and certain sedimentary rocks.

Dr J. C. Hopkins

In the report prepared by the Royal Society on the needs of fundamental research one section is devoted to work in biology. This appears to me to have received too little attention in to-day's discussion.

Perhaps it is that fundamental research, as a consequence of the war, is associated so much with atomic physics and extremely costly apparatus that insufficient stress is laid on what can be done by a scientist equipped with only a microscope and notebook and having the countryside for his laboratory. The natural history of the countryside has been studied intensively in Britain and other countries with a large population and a long established civilization, so that the fundamental biological work which can be accomplished by the field biologist is limited. This, however, does not apply to the Colonial Empire, much of which is still in a virgin state and whose peoples still lead relatively primitive lives and I would make an appeal for the encouragement of the isolated scientist stationed in these areas, who has not only adverse environmental conditions, and consequent diseases, to contend with, but so often is discouraged in his attempts at research by an unsympathetic officialdom, and I trust that this Conference may see its way to recommending ways by which the position of the isolated but keen man may be ameliorated. Professor Schonland has referred to the sense of frustration which often descends upon the university lecturer who has to devote nearly all his time to teaching and I would direct your attention to the similar position of the scientist in small and isolated territories.

There are wide fields awaiting close study in the sphere of taxonomy and ecology. Taxonomy must be recognized as fundamental to all bio-

logical sciences, including the microbiology of soils, whilst genetics provides clues to the vexed question of phylogeny and evolution. Without a detailed classification on which to build, research in applied science must be handicapped. It is in the realms of systematic collecting and recording that the scientist in remote and undeveloped areas can do so much of a fundamental nature, or at least be of great assistance to the larger herbaria and museums which are continually handicapped in the broader aspects of their work by lack of material. Systematic collection of terrestrial fauna and flora, which are the basis of human food, is as fundamentally important as the collection of marine animals and plants in the study of the food of whales.

Larger staffs for taxonomic work are required both in the bigger centres such as Kew as well as in the field of the largely unexplored areas of the Commonwealth.

Professor P. C. Mahalanobis

Professor P. C. Mahalanobis gave a brief review of the development of scientific research in India. 'English' as it is called in India but in fact modern scientific education was introduced about 130 years ago by the joint effort of great Indians and Britishers like Ram Mohan Roy and David Hare against the opposition of orthodox conservative groups on one hand and of government departments on the other. Medical training was started a little later by the government with the object of creating a number of low grade field assistants became more and more scientific in the course of time. Scientific surveys (trigonometric, meteorological, botanical, geological and zoological) were gradually established for strictly utilitarian purposes but served indirectly as centres of fundamental research in many directions depending a good deal, however, on the ability and initiative of individual officers. The first university was established in Calcutta about 90 years ago and a large number of other universities in the course of time in different parts of India.

Organized teaching in mathematics and science had been given from the very beginning, but real scientific research was started only about 60 years ago by a few pioneer workers here and for nearly 30 years remained practically the concern of adventurous individuals. During the last 25 or 30 years endowments were created for advanced scientific training and research and such activities gradually came to be recognized as a definite responsibility of the Indian universities. Institutions for research and study in special fields were also established either as private or autonomous bodies (usually receiving financial help from the government) or as official organizations under direct government control. A large number of scientific academies and societies both of the general and specialist types have also been gradually established. Research councils (medical agricultural, scientific and industrial) have been established by the government, and national laboratories are proposed to be set up in the near future.

Fundamental research is thus located at present in the universities and private or autonomous institutes as well as in officially controlled scientific surveys and institutions. The speaker was of opinion that government

controlled centres should specialize in applied problems with however freedom to take up fundamental research while non-official bodies should give greater emphasis on pure research but should, at the same time, undertake a good deal of applied work.

Because of the deplorably low level of living in India it was essential to give the highest priority to developmental work for some considerable time to come. At the same time there was an acute shortage of scientific man-power. It would be advantageous in every way therefore to make young scientists (with the possible exception of pure mathematicians) take up applied research for a few years in the beginning. Such work would serve as a proving ground for different kinds of aptitudes and abilities. Men would be sorted out and gradually diverted to more fundamental or more applied work on the basis of their actual achievements. In this plan vital contact would be maintained between applied and fundamental research which was essential for the sound progress of science. Finally, it would enable the universities and other non-official organizations to retain their own men and yet give them fullest opportunities to participate in national development.

Professor F. G. Soper

Whereas in applied research the need is primarily for trained staff of which there is a serious dearth, in fundamental research the need is for both staff and funds. Nevertheless, in spite of the heavy load of instructional and examining work which falls on university staffs in New Zealand, a surprising amount of fundamental research has been carried out and in this connexion names well known to this Society could be mentioned.

The need for greater expenditure in New Zealand on fundamental science is borne out by a comparison with the United Kingdom. It is difficult to give a figure for present research expenditure in the New Zealand University, but the Royal Society Report on 'Fundamental Research Needs' brings out the fact that about one half the cost of research is the cost of maintenance grants. The amount spent on maintenance grants may thus serve as a convenient yardstick for purposes of comparison.

In this country the amount spent on maintenance grants in 1939 was £137,000. To scale this sum down to New Zealand conditions we can reduce it by comparison with the numbers of university students in the two countries. The population of New Zealand is one-twentieth that of the United Kingdom and the ratio of student numbers is approximately one-tenth. Thus £13,700 would represent the expenditure which would be required in New Zealand to give a similar ratio of research students to total student numbers on the pre-war British standard.

The actual amount available for postgraduate maintenance in New Zealand is approximately £2,000 to which must be added the six Research Fellowships granted by the New Zealand D.S.I.R. held either overseas or within New Zealand. If half the latter are assumed to be held within the country, the grants available for postgraduate research in the New Zealand University are approximately one-fifth of the £13,700, which is the New Zealand equivalent of the British provision of maintenance grants in the pre-war years. Whilst this 1939 level is now regarded as quite

inadequate for the United Kingdom, it might well be aimed at as an initial goal for New Zealand.

There is no lack of fundamental research to be done in New Zealand and this applies particularly to the natural sciences and in chemical and physical applications thereto. The Ph.D. degree reintroduced this year, together with more maintenance grants for both junior and senior workers and provision for the costs of the work, will gradually, it is hoped, build up research schools which will supply some of the needs of New Zealand for research workers. It is also hoped that some of these schools may be strong enough to attract to New Zealand young graduates from the United Kingdom or Canada or other Dominions for postgraduate work in certain specialist fields—a two-way traffic which could be of the greatest benefit to the Empire.

MORNING SUBJECT (m)

THE ROYAL SOCIETY REPORT ON THE NEEDS OF RESEARCH IN FUNDAMENTAL SCIENCE AFTER THE WAR

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REPORT OF THE COUNCIL OF THE ROYAL SOCIETY ON THE PROVISION FOR RESEARCH IN CERTAIN FUNDAMENTAL SCIENCES, BASED ON THE REPORTS OF COMMITTEES APPOINTED OR INVITED TO CONSIDER POST-WAR NEEDS.

PART II

REPORTS OF THE COMMITTEES APPOINTED OR INVITED BY COUNCIL TO CONSIDER THE POST-WAR NEEDS FOR RESEARCH IN CERTAIN FUNDAMENTAL SCIENCES.

PART I

Report of the Council of the Royal Society on the provision for research in certain fundamental sciences, based on the reports of committees appointed or invited to consider post-war needs.

§1. ORIGIN AND SCOPE OF THE COMMITTEES

1. In October 1943, Sir Ralph Fowler and Professor Blackett sent a letter to the Secretaries which called attention to 'a danger that development in fundamental physics might be relatively neglected in comparison with applied physics, the development of which is now being actively pursued by various bodies.' They pointed out 'that it was no longer possible to leave the development of fundamental physics in this country entirely to the local initiative of the various universities, but that some central guidance on major matters of policy was not only desirable but essential, if the case for increased resources is to be adequately put to the relevant government authorities.' Consequently they urged that the Council of the Royal Society should set up a committee to consider the post-war needs of fundamental research in physics. They also suggested that the needs of other fundamental subjects should be reviewed, the general aim 'being to determine what steps should be taken, and by what persons or bodies, to ensure that the fundamental sciences in Great Britain should develop to the highest levels of fruitfulness and new discovery.'

It was realized that the universities would be making their individual claims to the University Grants Committee, but it was felt nevertheless to be highly desirable to present the claims of the fundamental sciences from the point of view of the advance of research on a national scale.

In the past, research in the universities has derived much support from private benefactions, from trusts and corporations and from industry, but in the future those sources of revenue, though much to be encouraged, will be insufficient to meet the needs, and the financing of research through the University Grants Committee, or whatever government body assumes the responsibility, is essential. The welfare of research in the universities is becoming a national

interest, and its support should be on such a scale as to ensure that the scientific departments of the universities are free to devote themselves to the search for new knowledge and to the training of students in the sciences and in methods of research.

2. Following on the receipt of the letter, a committee for post-war fundamental research in physics was set up by the Council of the Royal Society on 30 November 1943. Other committees were appointed on the dates mentioned in their several reports. Council decided that the Gassiot Committee should be charged with the duty of considering the needs for the advance of meteorological research and, as a sub-committee of the National Committee for Geodesy and Geophysics was already considering the needs of oceanography, it was agreed to wait for its report.

3. It is not to be supposed that the needs for the support of research over the whole range of the sciences are covered by the reports of these committees. Research in pure mathematics, which usually requires little in the way of apparatus, but is dependent on access to adequate library facilities, resembles in that respect and its consequent demands on government support, the researches of an arts department more nearly than those of one dealing with an experimental science. Subjects such as psychology and archaeology overlap in their interests with the faculties of moral philosophy, history and literature, and their needs have not been considered in these reports. The committees, again, have not specially reviewed the needs of those branches of experimental science, which, through their concern or association with practical applications, are already receiving government support on a large scale through the Advisory Councils on research in relation to medicine, agriculture and industry. Researches in physiology, anatomy, pathology and medicine are already largely supported by the Medical Research Council, and the Royal Society itself has important trust funds for the support of research in these medical fields. The needs of those subjects have further been under close discussion by the Inter-departmental Committee on Medical Schools, whose report was published last July. Of the subjects commonly included in the medical group, only the needs of biochemistry are considered in these reports. Government support of researches in agriculture and engineering has been regarded as primarily the concern of the Agricultural Research Council and the Department of Scientific and Industrial Research (D.S.I.R.), and they are accordingly not dealt with in the reports. On the other hand, certain applied, or partly applied sciences, such as geophysics and geography, have been dealt with in reports of the Royal Society's committees, on the ground that their needs were not elsewhere being considered. Recently a committee has been called by Council to consider the needs of astronomy.

4. The following reports were received from the committees and were considered by a Committee of Council on 26 July 1944, following the Council meeting to which they were submitted on 13 July:

Report of the committee on the needs for post-war fundamental research in physics.
Report of the committee on the needs for post-war research in chemistry.
Report of the committee on the post-war needs in biology and biochemistry.
Report of the committee on the post-war needs in geology.
Report of the committee on the post-war needs in geophysics.
Report of the committee on the post-war needs in geography.
Report of the Gassiot Committee on post-war research in pure meteorology.

Each committee reviewed the range of inquiry and the method to be adopted to obtain information from the various centres of research within its ambit. These reports and that of the committee for oceanography follow Council's review of the more general matters and form Part II of the Report.

5. The physics committee drew a useful distinction between what was termed 'ordinary' expenditure and 'extraordinary' expenditure for research, and it is a distinction which applies generally to the findings of all the committees.

(*a*) '*Ordinary*' *expenditure* relates to the sums of money likely to be required for all the usual expenses connected with running a research laboratory—maintenance grants for students in training in research, grants for senior research students or assistants, grants for technical assistants, for laboratory and workshop staff, for the usual equipment relating to the subject; in fact, all the expenses which should ordinarily be met out of departmental funds and grants to students.

(*b*) '*Extraordinary*' *expenditure* relates to expenditure involved in the purchase or construction of special items of apparatus or equipment, in the erection of special buildings or the acquisition of special staff above the normal, which might be necessitated by specially important or expensive fields of work in particular centres of scientific research, or which might be occasioned by unexpected developments in research for which no budget would have been possible. Such items, many of which would be for non-recurrent expenditure, would, in the normal course, not be met by funds at the disposal of the universities.

The recommendations of the committees have been reviewed by Council in accordance with their separation into these two categories. Many recommendations relating to 'ordinary' expenditure made by the committees were similar and could

therefore be considered together. Many of those relating to 'extraordinary' expenditure could not be brought within general recommendations, and require separate consideration. Section 2 deals with matters relating to 'ordinary' expenditure and Section 3 with those relating to 'extraordinary' expenditure.

§2. 'ORDINARY' EXPENDITURE

1. Council wishes to make it clear that, in its view, maintenance grants to students in training in research, grants for laboratory staff and general equipment, etc., are the special concern of the universities, and that it is aware that the University Grants Committee will have included such matters in their inquiries. Each committee set up by Council reviewed such matters from the point of view of the particular subject as a national whole, and made its recommendations because they are pertinent to the progress of research in that field.

Council has not specifically studied such questions as the desirable increase in academic staff, the extension of buildings, the financial provisions for meeting the standing expenses of university scientific departments. It considers these matters are directly the concern of the universities in their relations with the University Grants Committee. Council attaches much importance, however, to the increase in combined teaching and research posts (referred to in 3 (v) below), for it is a matter which greatly influences the progress of research. Maintenance grants for students in training, grants for senior research workers, and costs of providing research equipment and materials, or technical assistants for research, are also university matters, but they are essentially related only to research activities, and these were studied by the committees in more detail.

2. *General recommendations in relation to 'ordinary' expenditure*

Council desires to emphasize in particular two recommendations made by the committees in regard to 'ordinary' expenditure.

(*a*) First, Council is convinced that there should become available a very substantial increase over pre-war figures in the number of maintenance grants allotted to students for training in research, and therefore suggests that the whole question of the administration of such grants should be reviewed. It is not only desirable that the number of grants should be increased, but (i) the amount of the grant, (ii) the period for which it is made, (iii) the time of year at which grants are made, (iv) the balance in the number of grants given between the several subjects, and (v) the sources from which the grants should be made, are all matters which need review. While recognizing the valuable aid given to research, both in producing men trained in methods of research and also in augmenting the amount of research work done, which the D.S.I.R.

effected in their administration of maintenance allowances to students, it is clear from the figures given in Appendix I that 130 students in training in any one year costing about £100 each would be quite an inadequate total. While recognizing that the D.S.I.R. was not the only source from which such grants came, Council would favour a scheme by which the University Grants Committee included, in each block grant allotted to a university, an earmarked sum sufficient to cover the needs of the different scientific departments within that university for maintenance grants to students in training in scientific research, a machinery being created within the university in question for the allocation of grants to the students in the several scientific departments ; such machinery could then also be used for ascertaining the anticipated needs of the various departments for such maintenance grants, before the university made application for its grant from the University Grants Committee.

Training in research in applied science would still be the special care of the government Research Councils : though naturally nothing would prevent them from giving special assistance in any field of research, or to any laboratory or individual, when it seemed to them appropriate and useful.

(*b*) Secondly, Council was impressed by the necessity of a more ample provision for the research expenses of university departments and other research institutions, including in such provision funds for the payment of adequate laboratory staff and special technical assistants, and for meeting the expenses of running the general research work. Council considers that this provision could also be made as a sum earmarked for scientific research, provided for each university as an item of its block grant by the University Grants Committee. As in the case of the maintenance grants, machinery within the university would be needed for the allocation of general research grants to the several scientific departments.

3. *Discussion of the committees' reports relating to 'ordinary' expenditure.*

The general views of Council having thus been stated on the chief issues which would come under the heading of 'ordinary' expenditure, the various statements of the separate committees relating to 'ordinary' expenditure are brought together and discussed in this subsection, and a measure of the total sums of money needed for the various subjects and purposes is obtained.

(i) The committees which represent major branches of science (physics, chemistry, biology, geology) have gathered together information, from which an approximate estimate can be made of the sums of money likely to be required

to meet the needs of research in regard to the items of ordinary expenditure, mentioned in §1. 5 (*a*). In the following table are summarized the estimates given in the reports, making allowances to include all the centres to which inquiries were sent, and rounding off the totals.

TABLE I

TOTAL 'ORDINARY' EXPENDITURE BY SUBJECTS

	Average pre-1939	Estimate for normal post-war year
	£	£
Physics	103,000	300,000
Chemistry . . .	150,000	400,000
Geology	27,000	75,000
Biology and biochemistry .	86,000	225,000
Totals . .	£366,000	£1,000,000

'Ordinary' expenditure on research in these fundamental subjects will thus be likely to require between two and a half and three times what was spent in pre-war years, and the total estimate would amount to about one million pounds a year. This figure of a million pounds does not include the capital cost of building new laboratories, or extensions or renovations to laboratories which in many cases are required, in order that the increase in staff and research activities can be accommodated; these were considered to be a direct responsibility of the universities, and were therefore not included in the research bill. It also does not include the amount of the salaries of academic staff, but it does include the ordinary costs of their research work.

(ii) Table II summarizes and rounds off the estimate in another way: the grounds for the figures will be found in the following paragraphs, each item being discussed under a separate heading:

TABLE II

ANALYSIS OF 'ORDINARY' EXPENDITURE (FOR PHYSICS, CHEMISTRY, GEOLOGY, BIOLOGY)

	Pre-war	Post-war
	£	£
Maintenance grants to students in training	135,000	450,000
Grants to senior research workers . .	55,000	150,000
Laboratory and technical staff . .	75,000	175,000
Running cost of research . . .	100,000	225,000
Totals . .	£365,000	£1,000,000

The post-war costs estimated by the committees were made on the supposition that the £ would retain its pre-war purchasing power. The figures in Tables I to VI being based on the committees' estimates, are subject to the same supposition. It was not possible to foretell what the change in purchasing power would be, therefore the predicted costs of research and of laboratory staff would need to be adjusted to make suitable allowance for such change. Council, however,

considers that £220 per annum for the minimum maintenance grant for a student in training in research and between £400 and £600 for a senior research worker, are about of the right magnitude at the present date, and, unless there is a further big change in the purchasing power of the £, that the estimates for these items need not be subject to much adjustment. On the other hand, Council agrees that in regard to the effect of rise in prices and wages on the items 'running costs' and 'laboratory staff,' the estimates in the Tables and the total estimate of a million pounds will be subject to some increase.

(iii) *Maintenance grants to students*

The committees urged that materially increased numbers of students should be trained in the methods of research and that increased facilities should be available to enable students who have obtained an honours degree, or who have displayed aptitude for research, to have the opportunity to proceed to research, or to enable them to obtain additional training in order to equip them for research.

The committees also desired that the conditions governing the award of maintenance grants should be made more flexible than in the past, and made by means of a block grant from the government organization providing the grants (see § 2. 2 (*a*)).

It was the general view that £220 plus fees should be the minimum rate of allowance per student. The committees considered that it was desirable to enable students to reside away from home and to work in other university centres. It was also recommended that the maximum tenure of the grant should be 3 years rather than the present maximum of 2 years, so as to provide for the period of 3 years needed for the Ph.D. degree in many universities.

A summary of the figures relating to maintenance grants from all sources for students is given in Table III :

TABLE III

MAINTENANCE GRANTS FROM ALL SOURCES FOR STUDENTS IN TRAINING IN RESEARCH

	Average pre-1939		Estimated for normal post-war year	
	Number	Amount p.a.	Number	Amount
		£		£
Physics	270	32,000	460	110,000
Chemistry	590	63,000	930	204,000
Geology	86	10,000	150	36,000
Biology and Biochemistry	270	32,000	390	94,000
Totals	1,216	£137,000	1,930	£444,000

The total amount of the post-war allowances would amount to about three and a quarter times the pre-war amount, and it is indicated that there would be needed about 1·6 times the number of allowances. The total post-war number of students in training in research would be about 2,000 per annum, which, at the new rate suggested (£225 p.a.), would require about £450,000 per annum.

The committees intended that £220 per annum should be the *minimum* grant for a student living away from home. It is probable that some grants would be made to those who live at home and who would not be in need of a full

maintenance grant, whereas some would require substantially more than the minimum grant. The figure £225 per annum is adopted as a reasonable *average* maintenance grant for the purpose of this estimate.

In Appendix I there will be found a statement of maintenance grants provided to research students in training by the D.S.I.R. in years before the war. The total amount was only £13,500 a year averaged over the five years 1934–39. About 70 new maintenance allowances were made each year and most of them carried on for a second year. The number of new grants was between one-third and one-half of the total applications. No grants were made by the D.S.I.R. for training students in research in physiology or the medical sciences. The D.S.I.R. maintenance allowances only accounted for a small part of the pre-war total.

There are many other sources of grants available internal to the universities, as well as from external sources (Carnegie scholarships, local education authorities' grants, etc.) which are used to maintain students, while carrying out research. Many also maintain themselves out of their own resources. Figures in Table III relate to the total number of students in training in research and therefore include all such sources of maintenance. But it is clear that unless the grants from such other sources are also increased in number and amount, the number of grants made from direct government sources will have to be much increased.

(iv) *Grants to senior research workers and research assistants*

The committees were in agreement in recommending that the number of grants available for senior research students should be increased and that the value of such grants should be between a minimum of £400 and a maximum of £600 a year.

These grants should be so tenable that research can be carried out at home or abroad and should not restrict the grantee to work in one centre.

Several of the committees expressed the hope that further endowments will be made by industry and other bodies towards research, and that part of the additional expense of increasing the number of senior research workers can be met out of such funds.* Nevertheless, the main financial support for these grants, which are important for the progress of research, should be on a national basis.

TABLE IV

GRANTS FOR SENIOR RESEARCH WORKERS

	Average pre-1939		Estimate for normal post-war year	
	Number	Amount p.a.	Number	Amount
		£		£
Physics . .	45	13,500	104	52,000
Chemistry . .	95	28,500	160	80,000
Geology . .	10	3,000	30	12,000
Biology and biochemistry	34	10,000	90	34,000
Totals . .	184	£55,000	384	£178,000

* Imperial Chemical Industries have recently instituted a scheme of endowment of 80 research fellowships with an average value of £600 p.a. to be available in certain subjects and at certain universities.

The total number of senior research grants required would be about twice the number provided in a pre-war year, and, since the average grant would be increased from about £300 to about £460, the total amount required for such research grants would be three and a quarter times the pre-war; viz., about the same increase as was estimated in the case of the maintenance allowances for students in training. This would bring the total to 385 requiring about £180,000 p.a. A total of 300 to 350 awards might suffice, however, having in view a considerable increase in the number of those research workers, who would be paid as members of the academic staff of universities, in which case £150,000 p.a. might be the suitable provision as entered in Table II.

(v) *General considerations relating to grants to students*

Council strongly endorses the recommendation of the committees that the increase in senior personnel engaged on fundamental research in universities and university colleges should be effected mainly by an increase in the number of teaching posts giving adequate time for research. The staffs of the universities (particularly in the lecturer grades) will need to be very considerably increased * not only to cope with the increased number of students, but because it is highly desirable that these teachers should have adequate time to carry on research work and to look after the work of research students in training. Money spent on research students will be well spent only if money is spent on staff to train and guide them. Council accordingly recommends that this point should be brought with special emphasis to the notice of the University Grants Committee.

Council has already expressed its view (in § 2. 1.) that the main financial support of research in the fundamental sciences in the universities should be provided on a national basis through the University Grants Committee, and consideration will need to be given to the inclusion in the block grants of the sums of money needed at the various universities for maintenance grants to students in training in research, and for awards to senior research workers. The various scholarships, exhibitions, fellowships, etc., available to research students are fairly numerous. Many open scholarships and exhibitions are awarded (e.g. various Royal Society research studentships and fellowships and those of the 1851, the Leverhulme, the Salters' Company, etc.), and there are quite a number of closed scholarships given by universities and colleges from various endowments. There is no complete record of such grants, and it would be a big task to compile such a list. It would not be easy to classify the grants into the two categories, maintenance grants for students in training and senior research grants, because some scholarships given to undergraduate students by education authorities may often carry on into a period of research training and because the same grant-giving body may provide grants either to students in training in research or to more senior research workers.

A very rough indication of the amount of money which was employed in pre-war years in providing research grants in physics, chemistry, geology and biology (mainly for maintenance of research students in training and awards to senior workers) is given in a table in Appendix II, the data being obtained from university calendars, etc. The sum came to £90,000 per annum, which was about half the sum of the pre-war columns in Tables III and IV; the difference must be accounted for by education authority grants and unrecorded sources of assistance.

Whereas the amount of money required to maintain, in the four subjects, students in training in research and senior workers was some £190,000, the amount estimated for the post-war needs is £600,000, of which the existing sources would form quite a small fraction. Furthermore, many of the existing grants are individually quite small, and if the size of individual grants in future in increased, the total number available will be still smaller.

* The committees' figures indicate an increase of the order of 50 per cent.

(vi) *Laboratory staff*

The committees have expressed a general desire for the provision of more technical assistants of the trained specialist type and also of more general laboratory assistants, better workshop equipment and more laboratory mechanics in the various research laboratories, and have drawn special attention to the importance of this provision for the assistance of fundamental research. The younger generation of research workers, many of whom have worked in well-equipped new government establishments during the war, have learnt how progress can be hastened by provision of adequate facilities in the workshop and drawing office. Research leaders are also well aware of the advantage of making good use of research assistants, trained assistants to operate special instruments, or specialists in photographic or glass-blowing technique. The recommended proportion of laboratory assistants to research workers (1 : 3) was highest in the case of physics. An attempt has been made to reach an estimate of the sum which would procure improvements in such services ; the total comes to at least £175,000 a year without making allowances for any general rise in wages due to the reduction of purchasing power of the £. Council strongly supports the recommendation made by the committees that adequate funds should be provided in this category and that arrangements be made in good time so that men released from government laboratories and workshops can be employed. The importance of arranging centres of training for such laboratory staff was also stressed.

(vii) *Running expenses of research* (i.e. for normal equipment, apparatus and materials)

Block grants to universities by the University Grants Committee should include contributions towards the expenses of university departments and of research institutions under the wing of the universities ; these contributions should apply to the 'ordinary' expenses of running research in such departments or institutes and the provision of general equipment, apparatus and materials necessary to the type of research in hand, in addition to general laboratory expenses in regard to heating, lighting, cleaning and overhead charges ('standing charges'). It is very desirable that the heads of departments in the smaller universities should have at their disposal sufficient funds to ensure that the equipment for research and teaching in their departments is adequate, otherwise not only is the research which can be done in such centres curtailed, but also the teaching provided for the students suffers from a lack of the inspiration which a live centre of research of high quality produces in all concerned. Not only do the smaller universities cater for quite an appreciable proportion of the total output of graduates, but they appoint talented research workers to their staffs, whose potentialities will be lost to science in ill-equipped departments.

An estimate of the ordinary expenses likely to be associated with the carrying out of research by academic staff, by senior research workers and by students in training in research has been made.

TABLE V

COST OF RESEARCH

('Ordinary' equipment, material, etc., *excluding* 'standing charges' (gas, electricity, rent, etc.) and technical and workshop assistance)

	Pre-war Per annum	Post-war Per annum
	£	£
Physics	25,000	77,000
Chemistry	49,500	99,500
Geology	3,800	9,500
Biology and biochemistry	18,300	40,500
Totals	£96,600	£226,500

The figures provided by the committees indicate that the cost of research under this heading (vii) would amount to about £225,000 or rather more than double the pre-war cost. The cost for equipment and material per research worker (see Table VI) varies with both the subject and the class of worker; students in training in research would cost an amount nearer the lower figures of the 'spread' given in Table VI. It must be clearly understood that in Tables V and VI the estimates do *not* include workshop or other technical services or 'standing charges'; neither do they include 'extraordinary expenditure' for special equipment. They are subject to adjustment also for the fall in purchasing power of the £.

TABLE VI

APPROXIMATE RESEARCH EXPENSES PER RESEARCH WORKER *

(*not* including workshop or special technical services or standing charges)

	Pre-war Per annum	Post-war Per annum
Physics	£45 to £75	£75 to £115
Chemistry	£40 to £60	£60 to £80
Geology	£15 to £25	£25 to £35
Biology	£20 to £40	£30 to £70

(viii) *Administration*

The view has been expressed by several of the committees that the load of administrative work of research leaders and heads of departments should be lightened and that as much of their time as possible should be devoted to research and teaching. Research is exacting and calls for the full energy and zest of the leader and his team; enthusiasm may be discouraged by the difficulties of finding ways and means. In this connexion it was pointed out by the Chemistry Committee that there is need for simplification of the methods of obtaining grants for research students. The sources from which grants come are numerous and there is little co-ordination between them; difficulties are further increased by the terminal dates for application being often inconvenient. There is need for greater flexibility of the mechanism for provision of grants enabling heads of departments to plan their work ahead. It should not be necessary as at present for heads of departments to make application in detail for many different students to many different bodies in order to provide them with grants. The committees made various suggestions as to the way in which block grants might be made which will include maintenance grants and general research expenses. Council after discussing the various proposals has expressed its views in § 2. 2.

(ix) *Needs in regard to 'ordinary' expenditure in other subjects*

The needs discussed in the above paragraphs (i) to (viii) do not include those of other subjects such as meteorology, geophysics, geography, etc. Council desires to point out that awards for senior workers, maintenance grants for students, and research costs are needed similarly in these subjects, but the total amount required is small in comparison with the sums quoted for the other subjects, and can be met by allowing a reasonable margin on the total estimate for ordinary expenditure as defined in § 1. 5 (*a*) and as summarized—a margin of (say) £15,000 to £20,000 per annum. This margin should permit some special

* In some sciences—particularly physics—the cost per worker will be higher than here estimated during the immediate post-war period until stocks of apparatus have been obtained.

awards to senior workers in astronomy to be made. Council is favourable to the proposal to set up a National Oceanographical Institute and hopes that the sum of nearly £50,000 per annum required to run such an Institute will be provided.

§3. 'EXTRAORDINARY' EXPENDITURE

An estimate of the funds needed under the heading 'extraordinary expenditure' is not easily made; for it is in the nature of some 'extraordinary' requirements that these cannot be regularly foreseen and predicted. Each committee studied this aspect of expenditure and set out its several recommendations. As a result of their reports, Council has separated the grants for extraordinary expenditure into two categories (*a*) and (*b*), according to the amounts of expenditure involved and urges that:

(*a*) Treasury grants for exceptional purposes and large amounts should be made on the advice of the Royal Society;

(*b*) the Parliamentary Grant in aid of Scientific Investigations, administered by the Royal Society, should be very substantially augmented;

and further that as much flexibility as possible should be introduced in the system of administration of both such grants so that demands can be met at any time without undue delay.

Category (a)—Special Treasury grants

1. The intention is to include under this heading special grants made directly by the Treasury to meet requests for large sums of money, £2,000 and over, for special buildings, for special equipment or for special establishments, large expeditions or other substantial ventures. The following are examples: the Royal Society built and established (out of the Mond Fund) the Mond Laboratory for magnetic and low temperature research at Cambridge; the Admiralty engaged to provide H.M.S. 'Research' for magnetic survey; and the Treasury provided funds for the British share, including a ship, in the scheme of oceanographic research organized jointly by a Committee of the Royal Society from Bermuda and the Woods Hole Oceanographic Institution in Massachusetts. The giant cyclotron, built recently in California and the 200-inch mirror for Mount Palomar are examples of exceptional equipment, the expense of which was met by the Rockefeller Foundation.

2. It is often on the borderlines between the sciences that most activity takes place and from time to time demands arise for special departments, laboratories or institutes to develop certain fields of activity. Biochemistry is a case in point, the needs of which have been considered by the Biology Committee; oceanography is another example, and in this case there is the need for a National

Oceanographical Institute ; and there is at present in this country (unlike the U.S.A.) no properly equipped laboratory devoted to research in biophysics. Branches of physics or mathematics, such as statistics, aerodynamics, hydrodynamics, elasticity and thermodynamics can be the foundation for specialized departments of pure or applied science. From time to time there may be calls for special expenditure for the creation of such departments at the universities or elsewhere, which might involve special application to the Treasury.

3. It may also be mentioned in this connexion that in some countries special research institutes are being established, in which a single problem is subjected to a converging and concentrated attack by several different branches of science. Council considers that in most cases it will be more economical that this systematic attack should be accomplished through the close contact of, and freedom of movement within, the various existing university laboratories and research institutions of this country.

4. Assistance to special researches and expeditions in the past has often been provided by government departments, working in co-operation with the Royal Society, with valuable results to science, and extension of such co-operative enterprise in support of research is very desirable.

5. From time to time the necessity to support a proposal involving recurrent expenditure arises ; the International Seismological Summary mentioned in the Geophysical Committee's report is such a case, and in such cases assistance from the Treasury may be required.

6. It is of great importance to the progress of science that there should be means of providing special equipment and facilities for the rapid development of new fields of work. For instance in physical research special provision has had to be made for the installation of cyclotrons and other such equipment : similar provision may be required for biophysical research.

7. The Royal Society with its Committees and Boards is so constituted as to be able readily to advise the Treasury in regard to applications in category (*a*).

8. As already explained, it is not possible to state precisely the requirements of the various fundamental sciences in this category. The needs are likely to be unusually great during the first few years after the war, when it will be necessary to start many new projects if this country is to regain its position in the van of scientific progress.

Category (b)—Parliamentary grant in aid of scientific investigations

1. It is proposed that the grants in this category, for sums under about £2,000 in any single case, will be made by extension of the

existing 'parliamentary grant in aid of scientific investigations' which is administered by the Royal Society.

An analysis has been made of the grants applied for and the amounts granted in the years 1936–1939 (see Appendix III).

The grants can be divided according to their amount as follows :

Amount	1936	1937	1938	1939
£	£	£	£	£
0 — 150	3,787	3,530	3,221	2,558
150 — 249	1,483	300	1,670	1,205
over 249	830	4,033	1,840	2,553
Totals :	£6,100	£7,863	£6,731	£6,316

The annual total of the grants made amounted to sums from £6,000 to £8,000, of which about one-half was used for grants of over £150. The grants made for sums over £150 amounted only to about one-third of the total of applications for sums above that level (i.e., £13,914 out of £31,165).

2. The 'parliamentary grant in aid of scientific investigations' or 'government grant' as it is customarily called, has been used for the assistance of many researches and scientific expeditions which have had an important influence on the advance of the sciences.* There is no doubt that if more funds had been available, and if the conditions of grant had been broadened, many more applications would have been received and much other important work could have been accomplished. Council considers that it is very important for scientific progress that there should be a substantial fund available which can be used to promote and to support researches in the fundamental sciences and which is open to application from all quarters. The young, or independent, worker has often been unable to undertake, or proceed with, his investigations because funds were not provided for the specific purpose. There are also other cases where funds might have been available but were being allocated for other purposes by the authority in charge of the department in which the investigator was working. The independent worker not only should be in a position to lay out, at his discretion, the money available to him for the needs of his research, but also should be free to take his apparatus with him when he goes to pursue it elsewhere. The Royal Society, through the wide representation of the sciences within its Fellowship, and through the mechanism of its Boards whose constitution is not confined solely to its Fellowship but includes others whose advice may be valuable, is in a position to continue to administer such a fund,

* The 'government grant' dates from 1850. Originally £1000 p.a., it was increased to £5,000 in 1876, to £6,000 in 1920, and to £7,000 in 1936.

and it would be difficult to find in any other organization the range of experience needed.

3. From time to time it becomes of importance to facilitate the work of investigators of standing which shows special promise. The grants which were made by the D.S.I.R. for this purpose were of exceptional value (see Appendix I). They were not large but could be used for special equipment or special temporary assistance. While nothing would prevent the D.S.I.R., and the other Research Councils, from continuing to encourage research in this way, particularly in applied science, the Royal Society might extend the application of its 'government grant' to foster special lines of research, particularly of a fundamental character. In the past the grant has been mainly used for providing special equipment or expendable materials, for financing expeditions or for facilitating collections, but if the grant were made large enough its use could be extended to include the above purpose. Since the Royal Society's Government Grant Boards could meet more frequently, say three times annually, and since Council meets monthly for most of the year, grants could be made without undue delay, which is specially important in such cases. The Government Grant Boards should then be empowered to deal with applications for the expenses, not only of providing special equipment, but of employing the special research staff and temporary technical assistants needed for the particular research; while Council could deal with emergency applications of the same kind.

4. Council therefore strongly endorses the recommendation of the several post-war needs committees, that the parliamentary grant in aid of scientific investigations should be substantially increased; it recommends that this grant should be used to promote researches of special promise, to provide special equipment and material, to finance research expeditions and collections, and for such other purposes as require assistance up to a maximum of (say) £2,000 in any one case: and it estimates that the total amount of the annual grant required to deal adequately with such needs in the years immediately succeeding the end of the European war would be £20,000 to £25,000 p.a. or about three times the amount available before the war.

5. The normal equipment of university laboratories for research is a charge on the grants to those departments from university funds, and the 'government grant' should not be used for expenses which come naturally under the heading of 'ordinary expenditure.' With this in mind, some of the committees suggested that there might be a lower limit of £250 set to the individual grants made from the 'government grant,' considering that most small grants for research purposes could be met from the ordinary university funds at the disposal of the heads of departments. But there are numerous reasons why it is not advisable to set any such lower limit.

An applicant for a grant may not even be attached to a university department or he may need to carry the grant with him in a transfer to another department where the research for which the grant was made can be carried out ; and other reasons arise out of considerations to which attention has been drawn in paragraph 2 above. The proper distinction is not between larger and smaller needs, but between the normal equipment and resources of a laboratory and the special provision required for a particular research.

6. One of the committees called attention to the surplus government stock of scientific instruments, workshop equipment, etc., which could become available after the war, and which might be used to assist research in university laboratories without damaging the scientific instrument and machine tool industry (see Geophysics Committee Report). Council considers that this would be a very important assistance to research in the immediate post-war period and that the Royal Society could assist in the allocation of these instruments and machines if such a policy of disposal were agreed upon.

§4. TRAVEL GRANTS

1. The committees all desired that there should be closer collaboration with the universities and research institutions in the Dominions, the Colonies and India, and recommended that funds should be made available to provide opportunities for academic staff and research students to travel and work abroad, in order to acquire new technique and experience, to make desirable contacts, or to carry out researches where they can be done most effectively. This is a vital need, and in the past the paucity of financial provision to meet it has hindered progress. It is desirable that a fund providing (say) £15,000 to £20,000 per annum should be established for this purpose, and that it should be available not only to the research workers of the United Kingdom to provide them with opportunity to travel and work abroad but also to assist those from the British Commonwealth and Empire to visit this country. The need of increased provision for the transport of scientific expeditions is particularly urged in the report of the Geography Committee. Air travel tickets should be made available for such purposes. It was a recommendation of the British Commonwealth Science Committee of the Royal Society which reported to Council in 1943, that a fund for travel should be instituted ; and Council now recommends that this should be a subject for further discussion at an Empire scientific conference which it is hoped to arrange.

2. In the interests of scientific progress, it may often be desirable to invite foreign research workers to this country, and funds should be available for this purpose. It might, indeed, be a function of the British Council, on expert scientific advice, to provide means and facilities for such visits : at present there are very few funds which can be so used.

§5. PUBLICATION GRANTS

1. There is another important direction in which funds are required and on which Council desires to comment.

The publication of results of scientific investigations during the war has needed financial assistance between £5,000 and £6,000 per annum, over and above what the various scientific societies have provided from their own resources. This sum was provided partly out of the 'parliamentary grant in aid of scientific publication' administered by the Royal Society, and partly out of special wartime gifts generously put at the disposal of the Royal Society for the purpose by the Rockefeller Foundation and by the American Physiological Society. The amount of published matter has been between one-half and one-third of that before the war. After the war there will be a great accumulation of work to publish; there are indications that, in physics and chemistry alone, at least 2,000 separate papers will be released for publication. It will be impossible to publish these without substantial assistance from Treasury funds. Without their publication much of the advance of science during the war will go unrecorded, and British science will not obtain its share of the credit for what has been accomplished. There will also be need for reprinting to replace scientific publications and contents of libraries lost through enemy action.

2. The abstracting and documentation services, highly important for the advancement of science and essential for research, are a constant drain on the resources of the societies that undertake this work.

3. There are possibilities of small economies being achieved by collaboration between the various scientific publishing agencies, and measures are being explored.

4. The Treasury grant for scientific publication allocated by the Royal Society, which amounted to £2,500 a year before the war, will need to be about four times this sum for several years after the war, in order to meet the requirements for publication of scientific papers.

§6. RECOMMENDATIONS OF COMMITTEES WHICH REQUIRE SEPARATE ACTION

In this Report, those matters which have arisen out of the several committees' reports and recommendations and could be considered on a common basis, have been reviewed by Council. The many remaining recommendations, which cannot be so dealt with, are to be found in the committees' reports. Appropriate action is being taken by Council on the various recommendations, and in many cases such action will involve discussion and collaboration with various ministries and departments of State.

The list of recommendations to be dealt with in this category is as follows :

Biology and Biochemistry Committee : recommendations (C) 5, 6 ; 11–19 ; 19–32.

Geology Committee (E) 5, 6 ; 10–15 ; 17–32.

Geophysical Committee (D) 1–4 ; 7–18.

Geography Committee (F) 1–13.

There are also special recommendations in the Gassiot Committee's report on the needs of research in pure meteorology and in the report of the Oceanographical Subcommittee. The recommendations of the other committees have mostly come within the general category.

§7. SUMMARY

1. Council has reviewed the recommendations of the committees appointed to consider the post-war needs of research in fundamental science. The inquiry was limited in range and does not cover the whole field of science.

2. Research expenditure can conveniently be divided into '*ordinary expenditure*' which should be met in general out of departmental funds and grants to research students, and '*extraordinary expenditure*' required by important or expensive fields of research, or occasioned by unexpected developments.

3. Increased grants to universities and research institutions was be needed to meet the 'ordinary expenditure' necessary to progress in research. The financing of research on a national basis through the University Grants Committee, or whatever government bodies assume the responsibility, becomes essential to such progress.

4. Council would favour a scheme by which the University Grants Committee included in each block grant allotted to a university an earmarked sum sufficient to cover the needs of the different scientific departments within that university for maintenance grants for students in training in research ; machinery being created within the university for the allocation of grants to the students in the several scientific departments. It would favour a similar arrangement in regard to the normal costs of research in the various scientific departments of a university.

5. Council recognizes that 'ordinary' expenditure, as defined, would essentially be a matter for consideration between universities and the Universities Grants Committee. It has considered the matter only so far as scientific research is concerned. It has not dealt with the need for increased academic staff, for extension of buildings and accommodation, for increased funds needed to meet 'standing charges,' etc. It considers, however, that an increase in

the number of academic staff is of the highest importance, not only to provide teachers with time for research but to enable them to give due attention to those in training for research.

6. Council estimates that (excluding mathematics, engineering, medicine and the medical sciences) the normal ordinary expenditure which will be required for (*a*) maintenance grants to students in training in research, (*b*) grants to senior research workers, (*c*) costs of research equipment and materials, and (*d*) costs of laboratory staff, technical assistants and mechanics, will amount to about one million pounds per annum.

Details are given in the report (§ 2.3) of a comparison of pre-war and post-war expenditure under those headings for physics, chemistry, geology, biology (and biochemistry), and of the amount of the grants recommended.

If the estimate were to include all the sciences, it would be considerably higher ; the needs for 'ordinary expenditure' in geophysics and meteorology have been considered in some detail and would be covered by an additional grant of between £15,000 and £20,000 per annum.

7. Council strongly recommends increased provision for expenditure on laboratory staff, technical assistants and mechanics, as research has suffered from inadequate assistance of this kind in the past.

8. Council has examined needs under the heading 'extra-ordinary expenditure,' much of which being unforeseeable cannot be estimated. It comes to the conclusions that such needs could be met (*a*) by grants made directly by the Treasury on the advice of the Royal Society, in the case of applications relating to exceptional needs involving large sums (over £2,000), and (*b*) by a substantial increase of the 'Parliamentary grant for scientific investigations,' administered by the Royal Society, for sums amounting in any individual case to less than about £2,000.

9. The larger grants from the Treasury would be needed from time to time to provide new institutions, or large and expensive equipment and the staff needed in connexion with such equipment, or to meet the expenses of special new projects or expeditions.

10. It is recommended that the annual 'government grant for scientific investigations' should be at least three times its pre-war size ; and that it should be used for the initiation and furtherance of researches of special promise, for the assistance of scientific expeditions and collections, or for any purpose or means which helps the progress of research in the fundamental sciences, provided that no single grant for any specific purpose is more than £2,000.

11. Council records that the collaboration and assistance in the prosecution of special scientific research provided from time to time by government departments and government scientific establish-

ments has been of great assistance in the past to the progress of research and is confident that it will be continued in the future.

12. Council recommends that the allocation of scientific instruments and equipment from surplus government stocks after the war should be undertaken as an immediate assistance to research.

13. Council considers that there is great need for a travel fund to enable scientific research workers to go from one centre of research to another in order to further their work, and to provide closer scientific collaboration, particularly within the Empire. A sum of at least £15,000 per annum is needed for this purpose. Council recommends that the matter be further discussed at an Empire scientific conference.

14. Council notes the lack of funds available to enable foreign scientists to be invited to work in research laboratories in the United Kingdom, and recommends that provision should be made for the purpose.

15. Owing to the rise in the cost of publication and the large volume of work that will have to be published after the war, an increased grant for scientific publications will be required, and Council estimates that the annual Parliamentary grant for scientific publication should be increased to about £10,000 for the years immediately following the end of the war in Europe.

16. It is not possible to summarize the numerous recommendations of the committees in relation to specific research needs to which Council has decided to give individual attention.

APPENDIX I

D.S.I.R. GRANTS FOR YEARS 1934–1939

MAINTENANCE ALLOWANCES. Totals: all subjects.

	1st year of award		2nd year of award		Number of refusals
	No.	Amount	No.	Amount	
		£		£	
1934–35	76	8,365	63	8,155	141
1935–36	51	4,826	58	7,075	183
1936–37	75	6,810	36	4,200	107
1937–38	73	6,635	64	7,140	105
1938–39	74	6,675	66	7,740	98
Totals	349	£33,311	287	£34,310	634

Allocation according to subject was as follows :

	1934–35	35–36	36–37	37–38	38–39
Chemistry	58	55	60	62	58
Physics	29	22	20	29	36
Mathematics and Astronomy	9	5	3	2	2
Biology	30	20	20	28	32
Geology and Mineralogy .	4	8	4	3	—
Metallurgy	7	4	5	7	10
Engineering	15	7	9	8	1
Totals . .	152	121	121	139	139

About 70 new maintenance allowances were made each year in all subjects, and each award cost about £96 per annum. The total sum spent in the five years was £67,621.

SENIOR RESEARCH AWARDS

	1st year of award	2nd year of award	3rd year of award
1934–35	5	2	5
1935–36	7	5	2
1936–37	4	7	3
1937–38	4	2	4
1938–39	6	4	—

Thus about 5 new awards were made each year in all the subjects and each award cost about £260 a year : there were about 12 students receiving awards in any year. The total sum spent in the 5 years amounted to £15,465. The number of applications in any year amounted to about 20 on the average.

The distribution in subjects was as follows :

	1934–35	35–36	36–37	37–38	38–39
Chemistry	4	4	4	6	4
Physics	5	4	4	2	2
Mathematics and Astronomy	—	1	1	—	1
Biology	1	3	2	2	2
Geology and Mineralogy .	2	2	3	—	—
Metallurgy	—	—	—	—	1
Engineering	—	—	—	—	—
Totals . .	12	14	14	10	10

GRANTS FOR SPECIAL INVESTIGATIONS

The following table shows the grants made towards special investigations to research workers at universities and elsewhere in all subjects ; the total amounted in the 5 years to £57,194 for 272 grants amounting on the average to £210 each per year :

	1934–35	35–36	36–37	37–38	38–39
Number of grants (1st year)	33	39	43	38	41
Amount of grants . .	£6,916	£8,294	£8,787	£7,582	£9,256

(Some of the grants carried on for several years as indicated in the next table, and the total paid out in any one year amounted to a little more than £11,000 on the average.)

The number of grants made amounted to about two-thirds of the total number of applications. The grants were very useful to investigators.

The distribution of special grants according to subjects was as follows :

	1934–35	35–36	36–37	37–38	38–39
Chemistry	22	22	23	21	19
Physics	10	11	17	19	22
Mathematics and Astronomy	2	2	1	—	1
Biology	3	6	6	7	8
Geology and Mineralogy .	2	1	2	1	1
Metallurgy	5	5	4	3	1
Engineering	6	4	6	5	4
Totals . .	50	51	59	56	56

From the above, the following table of figures has been drawn up relating to grants per annum for physics and chemistry made by the D.S.I.R. They are only approximate and have not been submitted for the criticism of the D.S.I.R.

	Maintenance Allowances	Senior Research Awards	Special Grants	Total
	£	£	£	£
Physics and Mathematics	3,300	1,000	3,600	7,900
Chemistry . . .	6,200	1,100	4,500	11,800

APPENDIX II

GRANTS AVAILABLE TO RESEARCH STUDENTS IN UNIVERSITIES

A rough indication of the amount of money which was employed in pre-war years in providing research grants (mainly for maintenance of research students in training and awards to senior workers) has been gathered from the university calendars and other sources ; the statement makes no pretence at completeness (see Table). All grants for physiology and the medical sciences, and for mathematics, metallurgy and engineering are excluded.

	£
Open scholarships, etc., 1851, Ramsay, Salters, Leverhulme, etc.	15,000
Royal Society grants (excluding grants to professors) . .	8,000
Other open post-graduate scholarships available in universities .	12,000
D.S.I.R. grants	15,000
Closed (post-graduate) scholarships available in universities in England	20,000
Closed (post-graduate) scholarships available in universities in Scotland (including Carnegie)	20,000
Total . . .	£90,000

Sums received from unrecorded sources (grants from industry, local education authorities, special bursaries, grants from foundations such as the Rockefeller Foundation) are not included. The estimated pre-war figures for maintenance of students (£135,000) and senior grants (£55,000) based on the number doing research and their average rate of maintenance according to the committees' reports is £190,000. The difference between this sum and the estimates in the above table (£90,000), is accounted for, no doubt, by the grants from such unrecorded sources and by the private resources of many research students.

APPENDIX III

ANALYSIS OF SCIENTIFIC INVESTIGATIONS GRANT
1936 – 1939

(1) *Number of applications* : (2) *Amount applied for* : (3) *Amount granted* : (4) *Details of grant* :

Note : Columns (1) and (2) refer to the number and amount applied for in the two classes (£150–£249, and over £250) and do not correspond to the number and amount actually granted in those classes (columns (3) and (4)). The figures in brackets under (4) give the amount applied for when this is outside the limits £150 and £249. The total of all grants made includes those from £0 to £150 (see § 3, Category (*b*), 1).

1936 :

I Grants £150–£249 :

(1)	(2)	(3)	(4)		
7	£1,355	£1,483	(i) Cosmic rays . .	£198	(£497)
			(ii) Molecular spectra in ultra-violet . .	£200	(£350)
			(iii) Nuclear spin properties . . .	£200	
			(iv) Spectroscopic investigation of explosion flames . . .	£185	
			(v) Kerr effect and organic chemical problems . . .	£150	(£250)
			(vi) Great Barrier Reefs of Queensland . .	£200	
			(vii) Geological and cartographical survey of Ellesmere Land .	£200	
			(viii) Geology and glaciology of Eastern Himalaya . .	£150	

II Grants over £250 :

8	£4,587	£830	(i) Low temperature research . . .	£400
			(ii) Plant breeding .	£430
Total applied for :	£5,942	£2,313	Total of all grants made .	£6,100

(1) *Number of applications* : (2) *Amount applied for* : (3) *Amount granted* : (4) *Details of grant* :

1937 :

I Grants £150–£249 :

(1)	(2)	(3)	(4)
3	£500	£300	(i) Tidal currents . . . £150 (ii) Devonian faunas . . £150

II Grants over £250 :

(1)	(2)	(3)	(4)
13	£9,560	£4,033	(i) Movement of desert sand . £250 (ii) Photoelectric measuring optical constants of metals . £250 (iii) Surface structure . . £430 (iv) 1940 Eclipse . . . £600 (v) Structure of alloys . . £250 (vi) Genetical and ecological research at Potterne . . £430 (vii) Geological expedition to Rukwa . . . . £500 (viii) Photochemistry of visual purple . . . . £273 (ix) Ultracentrifuge . . . £250 (x) West Greenland expedition (cosmic ray research by high altitude balloons) . . £800
Total applied for :	£10,060	£4,333	Total of all grants made . £7,863

(1) *Number of applications* : (2) *Amount applied for* : (3) *Amount granted* : (4) *Details of grant* :

1938 :

I Grants £150–£249 :

(1)	(2)	(3)	(4)		
15	£2,825	£1,670	(i) Magnitude of the sun	£200	(£420)
			(ii) Mechanism of friction and electro-deposition	£200	(£488)
			(iii) Raman scattering .	£190	
			(iv) Neutrons and radio-activity . . .	£210	(£490)
			(v) *Scilla nutans* . .	£150	
			(vi) Chemistry of flower colour . . .	£150	
			(vii) Plant cells . .	£195	(£400)
			(viii) Entomological expedition to Yemen . .	£175	(£250)
			(ix) Geospizidae of the Galapagos . .	£200	

II Grants over £250 :

12	£5,948	£1,840	(i) Structure of proteins investigated by X-ray methods . . .	£450
			(ii) Low temperature research . . .	£400
			(iii) Ultra-violet spectra .	£360
			(iv) Cosmic ray phenomena in Wilson cloud chamber . . .	£360
			(v) Geological survey in Central Andes . .	£270
Total applied for :	£8,773	£3,510	Total of all grants made .	£6,731

(1) *Number of applications* : (2) *Amount applied for* : (3) *Amount granted* : (4) *Details of grant* :

1939 :

I Grants £150–£249 :

(1)	(2)	(3)	(4)		
9	£1,585	£1,205	(i) Crystal structures .	£150	(£285)
			(ii) Ocean bottom deposits . . .	£200	
			(iii) Bottom deposits of British Lakes . .	£150	
			(iv) *Scilla nutans* . .	£150	
			(v) Salt absorption in plant cells . .	£150	
			(vi) Plant cells . .	£205	
			(vii) Radcliffe Observatory, Pretoria . . .	£200	

II Grants over £250 :

(1)	(2)	(3)	(4)		
10	£4,805	£2,553	(i) Solar eclipse 1940 .	£825	
			(ii) Mechanism of friction	£250	
			(iii) Luminescence of solids	£328	
			(iv) Low temperature .	£300	
			(v) Infra-red and Raman spectra . . .	£300	
			(vi) X-ray structure of carbo-hydrates . .	£300	
			(vii) Central Asia Expedition . . .	£250	
Total applied for :	£6,390	£3,758	Total of all grants made .		£6,316

PART II

Reports of the Committees appointed by Council to consider the post-war needs for research in certain fundamental sciences.

PREFACE

The several committees have presented their reports each in their own way as suited the subject under review and not according to a common plan. Therefore some of the committees have dealt with the question of needs from a more general point of view than others, and have not submitted plans for specific research projects. It should not be assumed that, in such cases, the committees do not envisage that there are many research projects which should be initiated and developed.

Reports of Committees

A. Report of the post-war fundamental research in physics committee.

B. Report on the needs for post-war research in pure chemistry.

C. Report of the post-war needs in biology committee.

D. Report of the post-war needs in geophysics committee.

E. Report of the post-war needs in geology committee.

F. Report of the post-war needs in geography committee.

G. Report on post-war research in pure meteorology (Gassiot Committee).

H. Report on post-war research in oceanography (sub-committee for oceanography).

Appendices referred to in the reports have been omitted, but are available for reference at the office of the Royal Society. Council has appointed committees to consider further the special needs of astronomy and microbiology. Council has not yet given full consideration to all the recommendations in the reports, and it must not be assumed that it endorses them all without modification.

A. REPORT OF THE POST-WAR FUNDAMENTAL RESEARCH IN PHYSICS COMMITTEE

The Council at its meeting on 30 November 1943 appointed a committee consisting of:

Sir THOMAS MERTON, *Chairman*
Professor E. N. DA C. ANDRADE
Sir EDWARD APPLETON
Professor P. M. S. BLACKETT
Lord CHERWELL
Sir RALPH FOWLER
Professor H. R. ROBINSON
Professor G. I. TAYLOR
Professor A. M. TYNDALL
Ex officio:
Sir ALFRED EGERTON, *Physical Secretary*

to consider post-war needs in physical research.

The committee has met on three occasions.

Sir LAWRENCE BRAGG was invited to attend the committee on two occasions.

Professor E. J. WILLIAMS was invited to act as technical secretary by the committee but, owing to illness, was unable to do so.

In order to obtain the fullest information a questionnaire was prepared and circulated to the heads of departments of physics in the universities and university colleges of Great Britain and Northern Ireland. Twenty-six replies were received.

The questionnaire sought information on the following points: (*a*) the number of research students before the war and the number contemplated after the war; (*b*) the cost of research before the war and the estimated cost after the war; (*c*) the number of academic staff engaged on research before the war, and the number contemplated after the war, with information as to cost; and (*d*) the number of laboratory technicians and laboratory boys before the war, and the number contemplated after the war, with information as to cost. (It must be particularly emphasized that estimated post-war costs have in all cases been made on the supposition that the £ retains its pre-war purchasing power.)

The results of this inquiry are summarized in an appendix to this report.

It will be seen that a great increase in the numbers of research students, senior research assistants, academic staff and laboratory personnel is called for; a considerable increase in expenditure is also contemplated.

In the recommendations set out below, distinction has been drawn between ordinary and extraordinary expenditure. By ordinary expenditure is meant the normal year-to-year expenditure of a department necessitated by the systematic lines of research undertaken in the department. By extraordinary expenditure is meant such expenditure as may involve the purchase of single items of apparatus (say, of a cost of £1000 and upwards); the cost of special buildings; and the cost of special staff above the normal which may be necessitated by unexpected developments in research: in short, such items of expenditure as would normally be regarded as non-recurrent.

The committee's findings are epitomized in the following recommendations:

A 1. That a distinction be drawn between *ordinary* and *extraordinary* expenditure, the former being met by a specific allocation of an increased grant from the University Grants Committee.

A 2. That applications for extraordinary expenditure be made to H.M. Treasury, which shall act on the advice of expert bodies, such as the Royal Society, the D.S.I.R., the University Grants Committee.

A 3. That a sum be included in ordinary expenditure sufficient to enable the universities and university colleges to appoint an adequate number of research students.

A 4. That the rate of remuneration of such research students be at a minimum of £220 *plus* fees a year for a period of three years in all universities and university colleges.

A 5. That the increase in senior personnel engaged on fundamental research in universities and university colleges be effected by an increase in the number of teaching *plus* research posts.

A 6. That the number of laboratory staff (such as assistants and workshop personnel) be increased, a ratio of 1 to every 3 engaged on research being regarded as a reasonable establishment.

A 7. That, particularly in the period following the end of the war, facilities be made available (possibly through the agency of the British Council) for foreign research workers to undertake research at universities and university colleges in Great Britain and Northern Ireland.

A 8. That the parliamentary grant in aid of scientific investigations, administered by the Royal Society, be substantially increased.

(*Signed*) T. R. Merton.

Summary	Average pre-1939	Estimated normal post war year
Numbers of research students	(200)	(347)
Maintenance grants to research students	£24,000	£83,280
Research material for research students	£8,696	£26,936
Numbers of senior research students	(34)	(78)
Maintenance grants to senior research students	£10,200	£39,000
Research material for senior research assistants	£2,580	£8,987
Number of academic staff (research)	(142)	(220)
Research material for academic staff	£7,465	£21,784
Number of technicians	(98)	(172)
Salaries of technicians	£20,591	£47,200
Number of laboratory boys	(54)	(102)
Salaries of laboratory boys	£3,120	£9,763
Total costs	£76,652	£236,950

When the questionnaire was summarized replies had not been received from: Aberdeen; Aberystwyth; King's College, Newcastle; Royal Technical College, Glasgow; Liverpool; Oxford; Bedford College; Birkbeck College.

B. REPORT ON THE NEEDS FOR POST-WAR RESEARCH IN PURE CHEMISTRY

The Council at its meeting on 16 December 1943 appointed a committee consisting of:

Dr J. L. Simonsen, *Chairman*
Mr E. J. Bowen
Professor W. E. Garner
Professor I. M. Heilbron
Professor H. W. Melville

Professor E. K. Rideal
Sir Robert Robinson
Professor A. R. Todd
Ex officio :
Sir Thomas Merton, *Treasurer*
Sir Alfred Egerton, *Physical Secretary*

to consider the needs of post-war research in pure chemistry.

This committee has met on three occasions and after consideration of the information placed before it has agreed unanimously on a number of recommendations which, if implemented, should ensure that research in pure chemistry will in post-war years receive adequate support and recognition.

The committee is convinced that for the full development of research, not only must a greatly increased number of students be trained in the methods of research, but also that there should be increased facilities for senior research workers of exceptional promise to continue their work in the universities and university colleges. The committee regards its recommendations B 1 and B 3, below, to be of major importance. It feels that the conditions governing the award of maintenance grants, senior awards, and the allocation of funds for research must be given greater flexibility.

In order to arrive at an approximate estimate of the cost which their proposals would involve a questionnaire was addressed to Fellows who were heads of the departments of chemistry in the various universities and university colleges. They were asked to give approximate figures of the number of students who would register in their honours schools in normal post-war years and also for an estimate of the expenditure on research by staff and students in their departments. Whilst it is recognized that these figures can only be very approximate, it is not anticipated that they are likely to be far from the truth. From the figures (summarized on page 36) the committee estimate that if their recommendations are carried out the annual cost of research will be £400,000, and since the pre-war cost was approximately £150,000, the net increase will be £250,000.

Information was also obtained on the increase required in the laboratory staff of technical and other assistants, the nature of the research work contemplated and the special equipment which might be required. The committee agreed that in the past the funds which had been available for maintaining a staff of laboratory assistants, workshop mechanics and research assistants were inadequate, but that with adequate funds progress would be facilitated, and allowance had been made for this in the above estimate. Technical assistants were also much needed to operate special equipment and to relieve research workers from having to meet the requests by other departments for the facilities which such equipment provides. If such assistants were provided the special equipment could become more widely available. It was also felt that many of the smaller grants made for equipment should be met from funds provided to the chemistry departments of the universities for maintenance of research work, and that it should only be for the larger items of equipment for special purposes that special applications for grants should in future be necessary.

The committee reviewed the requirements for such equipment. While many departments will need more up-to-date equipment, and some departments will have demands for special equipment (e.g. infra-red, X-ray, etc.), the total sum of money in any one year involved is not likely to be large.

The committee would welcome far greater facilities being provided for research workers to visit and work in different laboratories within the Empire and also in foreign countries.

The committee summarize their discussions by making the following recommendations :

B 1. That all students obtaining an honours degree in chemistry, and being suitably recommended by heads of departments, be provided with full opportunity to proceed to research.

B 2. That the value of research studentships be at the minimum rate of £220 plus fees a year from all sources for a student not residing at home, the tenure of such studentships being normally for three years.

B 3. That the fees and maintenance grants payable to research students be made from a block grant direct to heads of departments by some central body.

B 4. That the block grant referred to in B 3, above, be allocated by the scientific departments controlled by the Lord President of the Council or by some other central body which may in future be established to deal with grants in aid of research.

B 5. That provision be made for the payment of senior research grants of the value of £400 (minimum) to £600 (maximum) a year and tenable at institutions at home or abroad.

B 6. That the grants referred to in B 5 be made on application to a central body either by the research worker himself supported by satisfactory external evidence, or on his behalf by a senior teacher in a university.

B 7. That applications for grants for the purchase and construction of apparatus, etc., to the value of £250 and upwards be made to H.M. Treasury through the Royal Society.

B 8. That on application a block grant should be made available to the head of a department to meet the cost of temporary technical assistants and technical services.

B 9. That there should be more flexibility in the machinery for governing the award of research studentships and also for the making of grants for expensive equipment, and that arrangements be made so that application for grants may be made at any time and can be considered without long delay. There is a necessity for adequate funds to be available to provide for investigations of special timeliness and promise.

B 10. That the Royal Society would welcome and support the establishment by industry of *open* research fellowships of the value of £400 to £500 a year, to be held in the universities or university colleges.

B 11. That the maintenance of the closest contact between universities and research institutions be regarded as most desirable ; and that such collaboration would be most valuable in making a concerted attack on problems of major importance.

B 12. That in order to aid post-war research in this country, there be maintained close collaboration with the universities and research institutions in the Dominions, the Colonies and India.

B 13. That the training of technical assistants be regarded as a matter of high importance.

B 14. That it is also necessary that additional funds be made available by H.M. Treasury for scientific publication.

(*Signed*) J. L. SIMONSEN.

ESTIMATED COST OF RESEARCH IN CHEMISTRY

—	Estimated number			Cost of maintenance		Cost of research (chemical, apparatus, etc.)		Total cost		Total increase in cost	Average cost per unit	
	1939	Normal post-war year	Increase	1939	Normal post-war year	1939	Normal post-war year	1939	Normal post-war year		1939	Normal post-war year
				£	£	£	£	£	£	£	£	£
Research students . .	590	930	340	63,000	204,000	35,000	68,000	98,000	272,000	174,000	166	293
Senior research workers .	95	160	65	28,500	80,000	5,500	13,000	34,000	93,000	59,000	358	581
Academic staff engaged on research	225	310	85	not applicable		9,000	18,600	9,000	18,600	9,600	40	60
				£91,500	£284,000	£49,500	£99,600	£141,000	£383,600	£242,600		

C. REPORT OF THE POST-WAR NEEDS IN BIOLOGY COMMITTEE

The Council at its meeting on 13 January 1944 appointed a committee consisting of:

Professor F. E. FRITSCH, *Chairman*
Professor W. BROWN
Dr O. M. B. BULMAN
Professor A. C. CHIBNALL
Dr C. FORSTER-COOPER
Professor H. MUNRO FOX
Professor J. GRAY
Professor J. B. S. HALDANE
Professor W. H. PEARSALL
*Dr E. J. SALISBURY
Dr V. B. WIGGLESWORTH
Ex officio :
Professor A. V. HILL, *Biological Secretary*

to consider post-war needs in biology.

Professor R. A. PETERS was later co-opted on to the committee.

The committee has met on five occasions. At the third meeting it was decided that Professor CHIBNALL and Professor R. A. PETERS be asked to form a sub-committee to deal with biochemistry, and that Professor CHIBNALL be the Chairman of the sub-committee. To this sub-committee were invited : Sir JACK DRUMMOND, Professor J. B. S. HALDANE, Professor F. G. MARRIAN, Professor H. RAISTRICK and Professor F. G. YOUNG. The committee presents the following unanimous report :

In considering the post-war needs of biology, we have largely concentrated attention on the momentary position and have made little endeavour to anticipate future developments in biological research which cannot be clearly envisaged at the present time. The development of other lines of research will certainly become necessary when the policy of the Government departments dealing with applied research have been formulated.

Fundamental research in biology (including biochemistry) has, in the past, been greatly hampered by the difficulty of obtaining adequate facilities and financial support, both for research workers and for large-scale research projects. Specific recommendations for improvement are made in paragraphs C 1–11.

Recent developments in the biological sciences are of two main types, those of a biochemical nature and those of a more purely biological character. The great developments in biochemistry justify a separate consideration of the needs of that aspect of biology (section III). With regard to other kinds of biological research, there are certain traditional morphological and physiological lines of approach, for which reasonable facilities already exist, and the principal improvements desirable here lie largely in the direction of securing the necessary personnel. There are other lines of biological inquiry, such as genetics and terrestrial ecology, for which the existing provision is far from adequate. Further, the universities, which are at present the chief centres for fundamental research in these directions, are mostly situated in industrial cities or in wholly urban surroundings, and facilities for the investigation of living plants and animals under natural conditions are rarely existent. The absence of such facilities almost prohibits the wider developments of fundamental genetical and ecological research that are becoming more and more pressing, as well as the study of the

* Dr E. J. SALISBURY was appointed a member of the Post-War Needs in Biology Committee by Council on 20 April 1944.

biology and physiology of an organism as a whole. The recommendations made in paragraphs C 12, 14 and 15 below are designed to remedy the disabilities which arise from this state of affairs.

Although we have understood our prime function to be a consideration of the post-war needs of biology in the direction of research, some attention has been given to the teaching of biological subjects (paragraphs C 14–17) and especially of biochemistry (section III), since the preliminary training of the student must materially influence the efficiency and outlook of the future research worker. For some types of research a broader training than is at present given seems desirable.

In order to obtain certain information a questionnaire was prepared and circulated to departments of biology in Great Britain. Although only 28 of the 81 questionnaires sent out were returned, the summary which is appended to this report may probably be taken as an average to indicate that, as regards research students and senior research workers, the pre-war grants should be approximately trebled. This does not include provision for research in biochemistry. No attempt has been made to assess the cost of other recommendations made by the committee, nor of the very considerable expansion of biochemistry which is envisaged (section III).

I. Personnel

One of the most pressing needs is improvement in the opportunities and facilities for research. In this connexion we make the following recommendations :

Studentships

C 1. It is essential that the number of post-graduate studentships be materially increased so that every student who has displayed aptitude for research during the period of undergraduate training shall have the opportunity of being trained in this direction. We hold the view that a period of research training is of the utmost value, even for those who do not necessarily envisage research as a career.

C 2. The value of studentships should be sufficient to enable the holder to take part in the social activities of the university to which he belongs. It is recommended that the remuneration attached to studentships should be at a minimum rate of £220 plus fees a year and that the tenure of studentships be for a period of three years (minimum). The same scale of remuneration should attach to post-graduate training grants.

C 3. Machinery should be set up to ensure that post-graduate students can proceed to the university or school where the best facilities for the prosecution of their particular lines of research are available.

C 4. To provide for research students of outstanding capacity, in the interval between the termination of the studentship and the occurrence of a suitable opening for a subsequent career, it is recommended that there should be established a number of Senior Research Studentships of the value of, say, £400 a year, the holder being required to undertake a certain amount of teaching. Such senior studentships should not be allowed to become permanent posts, although it is undesirable to fix any definite limit to their duration.

The Academic Staff

C 5. The time requirements for teaching among all grades of university staffs should be limited, and there should be freedom from such duties for, say, one term in each academic year. This is regarded as of prime importance in connexion with biological research where continuity of observation is often essential and where work may have to be carried out away from the university. It is realized that this recommendation will involve an increase in staffs.

C 6. A more frequent interchange of staff between universities and institutions of applied biology, as well as museums and botanic gardens, is strongly advocated.

C 7. We attach considerable importance to the practice of granting sabbatical periods to members of university and other research staffs.

Technical Assistants and Laboratory Staff

C 8. Biological research on the part of the staffs of universities is greatly hampered by the lack of adequate technical assistance. The provision of such assistance would greatly facilitate the pursuit of research by those engaged in teaching and administrative duties.

We therefore recommend that heads of departments be given, if required, the services of a technical assistant, who should have the status and training of a research assistant. Further, that every permanent member of the academic staff be given the services of a technical assistant, if required.

C 9. Laboratory assistants in university departments should be numerically increased and have an improved status. There is an urgent need for the creation of centres for the training of such assistants.

C. 10. Every biological department should have available the services of a secretary.

II. The development of fundamental research in biology

Outside the Universities

C 11. The existing organization for providing funds for fundamental research in biology outside the universities is inadequate, and it is essential to bridge the wide gaps that exist in this respect. Considerable funds are not only required for the further development of the marine institutions at Plymouth and elsewhere and of the freshwater institution at Wray Castle, but also for the land institution advocated under C 12 below and the maintenance of the collections referred to under C 13 below. The committee has devoted much time to the discussion of ways and means and has had the advantage of conferring with representatives of the Agricultural Research Council, the Department of Scientific and Industrial Research, the Development Commission and the Medical Research Council.

The following recommendations are made :

(i) That some permanent organization be established to consider the requirements for fundamental research in biology, especially for research of a long-term character. This organization should maintain the closest liaison with all government bodies administering grants in aid of biological research.

(ii) That, in order to ensure adequate support for fundamental research in which these bodies have no direct interest, a greatly increased grant should be made available to the Government Grant Committee of the Royal Society.

C 12. With advance in biological knowledge it has become increasingly evident that fundamental research must be directed towards the study of living organisms and of their relations with their natural surroundings. Such facilities as do exist for the study of living animals and plants under natural conditions deal almost only with marine and freshwater biology, and it is essential to develop opportunities for field research in terrestrial ecology in the widest sense.

It is therefore recommended that a research institute for ecological studies, with an adequate staff and equipment, be established, comparable to the marine and freshwater institutes at Plymouth and Wray Castle. The new institute might at first be located in a country house with a wide area of surrounding land.

Such a station would alone provide for the team work necessary to approach many fundamental problems of terrestrial ecology, which are outside the scope of existing applied institutions. Its activities would rapidly expand by the attraction of research students from the universities.

C 13. The maintenance of pure type-cultures of living micro-organisms, as well as of higher animals and plants of known genetic constitution, is regarded as of the highest importance.

Inside the Universities

No hard and fast limit can be drawn between research inside and outside the universities, and the recommendations made under C 11 above will also encompass research in the universities.

Whilst it has not been possible to consider the requirements of individual universities, who will no doubt themselves put these before the University Grants Committee, the following more general recommendations are made.

C 14. Future students of biology should have greatly increased facilities for study and experimentation with living animals and plants and for the study of terrestrial ecology in the widest sense. Greater facilities for keeping animals alive in the laboratory are needed, while in the case of universities situated in large towns many of the facilities mentioned in the first sentence could only be provided by the establishment of a field station within easy reach of the university in question and/or by courses at the institute of terrestrial ecology.

In this connexion the importance of nature reserves, where flora and fauna can be studied under natural conditions, may be emphasized.

C 15. It is essential that there should be adequate provision for the fundamental study of certain aspects of biology which are becoming of increasing importance in relation to economic and other problems. One such aspect is that of genetics. We recommend the strengthening of existing departments of genetics and, if necessary, the establishment of others. There should be attached to each such department a field station for training and research in animal and plant genetics, at least one member of the staff of the department being permanently attached to the station. Facilities for study by external students should be provided at such stations.

C 16. The facilities of existing research institutions, both pure and applied, including museums and botanic gardens, should be developed for the training of selected groups of university students in their special fields of biology. It is held that this will be of benefit, not only to the universities, but also to the institutions themselves.

C 17. It is desirable to bring about a closer co-ordination, both in research and teaching, between the various branches of biological science dealing with animals and plants respectively. Certain aspects of the subject merit greater prominence in the general curriculum ; examples are afforded by microbiology (including general bacteriology) and limnology (freshwater biology). There is also a dearth of opportunity for training in methods of taxonomy ; this might best be secured by co-operation with museums and botanic gardens. Improvement would be effected by the establishment in suitable centres of a limited number of readerships in these various topics.

C 18. Advanced teaching and research in some of the more specialized branches of biology (e.g. palaeobotany, limnology) might with advantage be concentrated at a limited number of universities where special facilities exist for their pursuit.

III. Post-war needs of biochemistry in the universities

During the past twenty years all aspects of biochemistry have made extremely rapid progress. In the early years, that is before 1920, the encouragement to develop the subject came largely from the medical schools. There was, in

consequence, a natural tendency in universities to look upon it as an offshoot of physiology and, in fact, as nothing more than the handmaid of medicine. But to-day the subject has attained a position in the scientific world comparable with a major science. It has become indeed a science on its own—distinct in its discipline, technique and approach from its parent subjects of chemistry and biology.

Nevertheless, it is not easy to define the present-day boundaries of biochemistry as a science, for it is really the connecting link between many fields of specialized knowledge. Biochemists to-day are actively collaborating with physiologists, physical chemists and organic chemists, as well as with those whose prime interest is in the biological sciences, medicine or agriculture. Indeed the Annual Review of Biochemistry for 1942, which covers only a selected number of topics, deals with the work of more than 3000 independent investigators. During the past few years this interest in biochemical research, especially where it has meant collaboration with one of the other sciences mentioned above, has been growing at an ever accelerating rate, and until the present war was confined very largely, and in approximately equal amount, to workers in the U.S.A., Great Britain and Germany with Scandinavia. Since the war, however, which has diverted the attention of many of the workers in Great Britain and has interrupted the flow of new recruits, the focus of research has shifted appreciably in favour of the U.S.A. to an extent that cannot but cause uneasiness to those in Great Britain responsible for the training of students and research workers, and for the initiation of research. We regard it as vital therefore that in the immediate post-war years a determined effort should be made to re-assert the position of Great Britain and the Commonwealth in this new and flourishing science. This calls for an enlightened policy on behalf of the universities themselves, and of those responsible for the appropriation of public funds for research. We therefore make the following recommendations.

Departments of Biochemistry in the Universities

C 19. In biochemistry, as in other subjects, the chief source of men and of ideas will probably be the academic teaching departments of the universities. On account of the almost total cessation of the flow of recruits into the profession during the past four years, and particularly of the rapid expansion to be expected in the activities mentioned under B 21 below, we consider it desirable that all universities should possess departments of biochemistry in the Faculty of Science where the fundamentals and theoretical branches of the subject will be particularly stressed, without undue emphasis being laid on its application. The institution of a comprehensive syllabus of biochemistry within a properly integrated department should help to eliminate the senseless overlapping and repetition of teaching of biochemical subjects in several departments, a condition which holds in many universities at the present time.

C 20. With this end in view all those universities which do not as yet possess departments of biochemistry in the Faculty of Science should be encouraged to create them as soon as possible after the war. The department of biochemistry should not be contained within or under the control of any other department, but to obtain effective collaboration in research it should be placed geographically in close proximity to the departments of organic and physical chemistry and of the fundamental biological sciences.

C 21. All universities in which departments of biochemistry in the Faculty of Science are established should give courses leading to an honours degree in biochemistry. In his early years the student should be given the necessary grounding in both physical and organic chemistry, and in one, or preferably two, of the subjects botany, zoology, biology and physiology. These courses should be given in, or in collaboration with, the departments concerned. The student's subsequent training in biochemistry will have to depend somewhat on the various degree regulations of his university; he might take (*a*) third and fourth year courses leading to the Honours B.Sc. degree, followed by two years'

research for the Ph.D., or (*b*) a third year course leading to the Honours B.Sc. (or B.A.) degree, followed by three years for the Ph.D., in the first of which he should do approximately another year's course work. A curriculum extending over a full six years is considered to be the minimum required to train a competent biochemist.

C 22. Biochemistry attracts the specialist in physical chemistry, organic chemistry, physiological chemistry, pathological chemistry, immuno-chemistry, microbiological chemistry and plant chemistry. Not all of these branches will be represented in the biochemical department of any one university. Nevertheless, we regard a staff consisting of a professor, a reader, two lecturers and two demonstrators as the minimum requisite to cover the general fundamental teaching outlined in paragraph C 21. British biochemistry is in grave danger of losing its prominent place in world science if such an expansion of staff as that envisaged above does not take place. A small staff cannot possibly be expected to cover the complex and highly specialized nature of the different branches represented in the more advanced teaching.

C 23. An increasing number of biochemists is being successfully employed in the ancillary medical services, in institutes for medical research, in institutes for agricultural research and in most of the industries concerned with natural products (e.g. foods and drugs). This wide application of the methods, as well as of the discoveries, of biochemistry entitles the subject to an influential place in the vocational colleges and schools of the universities.

C 24. Applied biochemistry will occupy—does occupy indeed—as prominent a position in the industry of the mid-twentieth century as chemical engineering did in the early decade of this century. Applied biochemistry should accordingly be given as prominent a place in the Faculty of Engineering of certain selected universities as chemical engineering has found in the past. The subject of applied biochemistry should include the large-scale preparation of biological products.

C 25. The expansion in agricultural research that will undoubtedly take place after the war will call for the services of biochemists with specialized training. In certain universities or university colleges, therefore, where the local conditions or associations are suitable, the orienting of the teaching and research in the department of biochemistry towards one or more of the branches, plant biochemistry, insect biochemistry, veterinary biochemistry, comparative biochemistry and microbiological chemistry, should be encouraged.

C 26. It must be clearly realized that the large increases in staff—both senior and junior—which we consider necessary for the full development of biochemistry in universities and in the vocational colleges will be difficult of attainment if the salaries offered do not fall into line with those obtainable by men or women of similar age and ability in medicine and industry.

Departments of biochemistry in the medical schools

C 27. The application of chemical methods to the problems of clinical medicine has achieved outstanding results, as did the earlier application of similar methods to the study of function. In the medical curriculum biochemistry has therefore a clinical significance as well as a pre-clinical one. In all medical schools the department of biochemistry should be sufficiently large to cover the more advanced applied and clinical features of the subject, as well as its fundamental and functional aspects. Where clinical departments of pathological chemistry already exist, the closest co-operation should be maintained with the department of biochemistry, both with respect to teaching and research. In general, the activities of the department of biochemistry should subsume the teaching of chemical matters throughout the medical curriculum, and the professor should have associated with him a staff as adequate in number and seniority as that mentioned in paragraph C 22. It is suggested that in most universities, where there is the dual task of training students in scientific as well

as medical biochemistry, it is usually more efficient and better for each aspect to combine the biochemical teaching in the faculties of science and medicine in one department.

Research

C 28. In many of the more specialized fields of biochemical research to-day it is necessary, if the maximum success is to be achieved, for the group leader to have with him not only a number of junior workers who will normally come and go, but also one or more fairly senior people who have acquired a mastery of the particular technique concerned and whose services can be retained for a number of years to help teach and guide the youngsters, as well as to take a full share in the work. It is therefore suggested that one of the most urgent needs for the immediate post-war years is the establishment of posts of this type. They should be *ad hoc* terminable appointments for so many years, with a salary graded according to circumstances—say, £500–£600 per annum on a 1939 basis. As the number of such appointments is likely to be small, the universities should make the necessary provision.

C 29. The development of most lines of biochemical research generally demands the continuous repetition of some exacting technique. Research students should not be called upon to do such work for longer than is necessary for them to master this technique, and the work should normally be done by a technical assistant. There is therefore an urgent need for an increase in the number of technicians who can be employed exclusively on research (see paragraph C 8).

C 30. There is an urgent need for the establishment of an Institute of General Microbiology, to carry on research on fundamental and applied problems. It should train biochemists in microbiology, house a proportion of workers financed by D.S.I.R., M.R.C. and A.R.C., and co-operate with industrial research. It should be the focal point for microbiological research in this country and for the Empire, and besides training and research it should have advisory and consultative functions. It might house the National Type Collections (see paragraph C 13) for all except the pathogenic organisms.

C 31. Biochemistry is a subject of recent growth, and it is still growing. In the pre-war years only two of our universities provided courses in biochemistry leading to a first degree. It is therefore impossible to forecast the number of undergraduate and graduate workers that the various universities must cater for in the post-war period. Attention can be drawn however to the fact that biochemists often work with expensive biological material and that they use the technique of both the chemist and the physiologist. The overhead cost of a research worker is thus higher than in either of the two latter subjects—in 1939 it was probably between £150 and £170 per annum.

C 32. If biochemical research in this country is not further to lag behind that in America (especially) and other countries, it will be necessary to provide adequate funds for the establishment of centres to cater for the highly specialized needs that will be common to most, if not all, research laboratories. We may instance the provision of rare chemicals, radio-active isotopes, standardized animals, etc.

Summary of Principal Recommendations

Personnel

C 1-2. That the number of postgraduate studentships and training grants be materially increased and that the remuneration be at a minimum rate of £220 plus fees a year, with a minimum tenure of three years.

C 4. That a number of Senior Research Studentships of, say, £400 a year be established.

C 5. That all grades of university staffs be free from teaching duties for, say, one term in each academic year, so as to admit of that continuity of observation which is so essential in biological research.

C 6. That there should be an interchange of staff between universities and institutions of applied biology (including museums and botanic gardens).

C 8-9. That there should be a greatly increased provision of technical assistants, as well as of laboratory assistants.

C 9. That centres for the training of biological laboratory assistants be established.

Research

C 11. That, in order to bridge the wide gaps in the existing organization for the provision of funds for research in biology, especially outside the universities, some permanent organization be established to consider the requirements of fundamental research in biology, especially for research of a long-term character.

That a greatly increased grant be made available to the Government Grant Committee of the Royal Society.

C 12. That a research institute for ecological studies, with an adequate staff and equipment, be established.

C 13. That it is essential to maintain pure type-cultures of living micro-organisms, as well as of higher plants and animals of known genetic constitution.

C 14. That increased facilities for keeping animals alive in the laboratory be provided.

That it is essential to increase the opportunities for students of biology to study living animals and plants in nature and that, in the case of many universities, this can only be attained by the establishment of field stations.

C 15. That existing departments of genetics be strengthened and, if necessary, others established. That there should be attached to each such department a field station for training and research in animal and plant genetics.

C 16. That the facilities of existing research institutions (including museums and botanic gardens) be developed for the training of selected groups of university students in research in fundamental aspects of biology.

C 19. That improvement in the teaching of such topics, as methods of taxonomy, microbiology (including general bacteriology) and limnology, will be best obtained by the establishment in suitable centres of a limited number of readerships in these topics.

Biochemistry

C 19-20. That independent departments of biochemistry in the Faculty of Science, not contained within or under the control of any other department, be established in all universities.

C 21, 25. That all such departments should give courses leading to an honours degree in biochemistry. That, where the local conditions or associations are suitable, teaching and research in the department be oriented towards one or more of the branches plant biochemistry, insect biochemistry, veterinary biochemistry, etc.

C 22. That the minimum staff for each such department be a professor, a reader, two lecturers and two demonstrators, the salaries being commensurate with those obtainable in medicine and industry.

C 27. That, since in the medical curriculum biochemistry has a clinical as well as a pre-clinical significance, the department of biochemistry of all medical schools should be sufficiently large to cover more advanced, applied and clinical features of the subject, as well as its fundamental and functional aspects.

In most universities, where there is the duel task of training students in scientific as well as medical biochemistry, it is suggested that it will usually be more efficient and better for each aspect to combine the biochemical teaching in the faculties of science and medicine in one department.

C 24. That applied biochemistry (including the large-scale preparation of biological products) be given a prominent place in the Faculty of Engineering of certain selected universities.

C 28. That, in the more specialized fields of biochemical research, the group leader should command the services of one or more senior people expert in the particular technique concerned ; such senior workers occupying *ad hoc* terminable appointments for so many years, with a salary, say, of £500–£600 per annum on a 1939 basis.

C 30. That there is urgent need for the establishment of an institute of general microbiology, which should be the focal point for microbiological research in the Empire, and should also have advisory and consultative functions.

C 32. That it is necessary to establish centres for the provision of rare chemicals, radio-active isotopes, standardized animals, etc.

(*Signed*) F. E. FRITSCH.

SUMMARY OF COSTS

	Average pre-1939	Estimated Normal post-war year
Numbers of research students	(135)	(195)
Maintenance grants to research workers	£16,200	£46,800
Research material for research workers	£2,970	£5,420
Numbers of senior research students	(17)	(45)
Maintenance grants to senior research assistants	£5,100	£17,200
Research material for senior research assistants	£405	£2,070
Number of academic staff (research)	(135)	(185)
Research material for academic staff	£5,765	£13,075
Number of technicians	(55)	(98)
Salaries of technicians	£10,070	£24,000
Number of laboratory boys	(44)	(78)
Salaries of laboratory boys	£2,340	£6,567
Totals	£42,850	£115,132

D. REPORT OF THE POST-WAR NEEDS IN GEOPHYSICS COMMITTEE

The Council at its meeting on 17 February 1944 appointed a committee consisting of :

Sir GERALD LENOX-CONYNGHAM, *Chairman*
Dr E. B. BAILEY
Dr E. C. BULLARD
Professor S. CHAPMAN

Vice-Admiral Sir JOHN EDGELL
Dr H. JEFFREYS
Dr A. O. RANKINE
*Brigadier B. F. J. SCHONLAND
Professor G. I. TAYLOR
Professor C. E. TILLEY
Ex officio :
Sir THOMAS MERTON, *Treasurer*
Sir ALFRED EGERTON, *Physical Secretary*

to consider post-war needs in geophysical research. The committee has met on three occasions.

Sir GERALD LENOX-CONYNGHAM was prevented by illness from acting as chairman of the committee ; Dr A. O. RANKINE acted as chairman when the report was completed. Sir EDWARD APPLETON attended a meeting of the committee and gave his views on the needs for the development of ionospheric researches (see memorandum 9).

Professor P. M. S. BLACKETT was invited but unable to attend the committee meeting. He wrote a note in regard to the systematic recording of cosmic-ray phenomena (see memorandum 10).

We have considered that geophysics for the purposes of the committee includes geodesy, seismology, terrestrial magnetism and electricity (including the study of the ionosphere), and the study of the earth's internal heat. We have excluded oceanography as we understand that it is being dealt with by the National Committee on Oceanography, meteorology because it is being dealt with by the Meteorological Research Committee and the Gassiot Committee, and hydrology because we considered it could best be dealt with by the committees on post-war needs in geography and geology. We particularly wish to emphasize that the absence of recommendations on these important subjects is solely due to a wish to avoid unnecessary duplication. We have given no consideration to vulcanology owing to the meagre scale on which active volcanoes occur in the Empire.

In physics, chemistry and other long-established subjects there exist numerous university departments engaged in undergraduate teaching and in research, and a large part of the work of the committees dealing with these subjects consists in an analysis of their resources and needs. In geophysics this is not so, as before the war relatively little attention was given to the subject and it so happens that a large part of the pre-war provision has now come to an end. The first requirement for the development of the subject is that there should be university departments where such work can be carried on and where research students can be trained. Our resolutions D 1 and D 2 deal with this matter. The need for theoretical as well as experimental workers should not be lost sight of. In pre-war years there were undesirably few research students working on theoretical 'classical' physics and its application to geophysics. A first-rate knowledge of hydrodynamics and the theory of elasticity with a general knowledge of physics and geology would be the desirable combination of studies.

As to the finance of university departments we are in agreement with the resolutions A 1-6 and A 8 of the committee on post-war needs in physics. The only specific scheme that we have considered is that at present under discussion by Cambridge University : this involves an increase in expenditure from £2,000 to £7,000 per year, including salaries but not including payments to research

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* Brigadier B. F. J. SCHONLAND has been prevented by duty from attending the meetings, but sent the chairman, after the completion of the report, a letter relating to applied geophysics and a note on seismology in South Africa which appear in memorandum 12.

students, or the expenses of the International Seismological Summary. The expenses of the section of applied geophysics at Imperial College are included in the totals of the Physics Committee.

We regard it as of special importance that there should be more facilities for workers from abroad, particularly from the Empire, to work in British universities and also that more facilities are required to enable British workers to work abroad, both in universities and in the field, on problems of geophysical interest. This is covered by our resolutions D 5 and D 6. We have not tried to produce a detailed scheme as the question affects all the sciences and involves some difficulties, the principal of which is to ensure that the best men in the dominions and colonies are encouraged to return and are not lost to their home countries.

The provision for the development of geophysical instruments has not been satisfactory in this country. There is much work of this kind that cannot suitably be done in universities and which is unlikely to be done by commercial firms. We consider that it is desirable that the National Physical Laboratory should take up such work (recommendation D 3).

The data of geophysics are partly collected by systematic observation over a long period of time and cannot all be gathered in this country. Observatories of various kinds play an essential part. In our recommendations D 7, D 8 and D 9 we make suggestions as to the most important lines to pursue.

Many branches of the subject are best dealt with by special expeditions despatched for the purpose. It is not possible in this report to give an exhaustive list of possible projects, but we would draw attention particularly to cosmic rays, and to the study of the floor of the oceans ; resolution D 16 refers to this.

In seismology the data from the observatories are of little use until the epicentres of the earthquakes and the residuals in the arrival times at the stations have been calculated. This has been the work of the International Seismological Summary. Owing to lack of money it has been falling more and more behind-hand and seems likely to stop altogether. Our recommendation D 4 deals with this. The cost is estimated at £1,600 per year, of which about £900 was available before the war but only a few hundred will be available after the war. It seems doubtful if we can expect any of the cost to be met from international funds, at any rate for a few years after the war.

Recommendation D 10 deals with surplus government apparatus. We consider that great benefit would be derived from a suitable distribution of such apparatus and that it is important that it be organized in such a way as not to do harm to the instrument industry.

Our remaining recommendations, D 11-18, deal with particular matters on which we think work is desirable, but which do not need special comment here.

Various members of the committee have prepared notes on particular aspects of the subject. We are in general agreement with these and attach a list (see memoranda) of their titles in the belief that they may be of use in supplementing this report.

Recommendations

I. *Projects involving a substantial recurrent expenditure in addition to that already available*

D 1. That the proposals for extending the department of geodesy and geophysics at Cambridge be approved ; that the section of applied geophysics at Imperial College be revived and strengthened ; and that proposals from other universities and university colleges for similar facilities be sympathetically received.

D 2. That funds be made available for the maintenance of students at such places.

D 3. That facilities be provided at the National Physical Laboratory for the development and testing of instruments for geophysical investigations and that geophysical work be included in the activities of the Geological Survey.

D 4. That the continuance of the International Seismological Summary be regarded as a matter of importance, that British funds be made available for it (the estimate given by Dr H. JEFFREYS being approved), and that in the future the work be carried out at Cambridge.

D 5. That additional facilities ought to be made available to enable research workers from overseas to carry out research in British universities.

D 6. That additional facilities ought to be made available to enable British research students to carry out research abroad.

II. *Other Projects*

D 7. That in a few cases where the results are likely to be specially valuable magnetic and meteorological observatories in the British colonies be equipped with seismological instruments.

D 8. That the work on the ionosphere carried out during the war be continued, special attention being paid to (*a*) the morphology of the *F* layer; (*b*) the reflexion co-efficient of the ionosphere; and that in addition to observatory work, funds be made available for the organizing of special expeditions for this purpose.

D 9. That additional magnetic observatories are required in India and in certain parts of the Colonial Empire. Attention is drawn to the memorandum on the subject at present before the Colonial Research and Development Committee. Some of the ionosphere work referred to in D 8 might be done in magnetic observatories.

D 10. That there be established, before the end of the war, a committee, representing the Royal Society, the instrument industry and the service supply departments, to consider the question of the disposal of surplus instruments.

D 11. That the project begun before the war for the measurement of gravity at sea be resumed at the appropriate time.

D 12. That the Colonial Survey Committee of the Colonial Office be asked to consider the practicability of applying radar to survey work.

D 13. That up to 1,000 tons of surplus government explosives be reserved for seismological work, and that at the appropriate time a committee be set up to advise on the use of these explosives.

D 14. That it is desirable that investigations on the behaviour of rocks and minerals under high pressure should be carried out.

D 15. That the gathering of further information as to temperature and therma conductivity of rocks from borings is desirable.

D 16. That it is desirable that support be given to expeditions to investigate geophysical problems. We regard the study of cosmic rays and of the ocean floor as particularly important.

D 17. That it is to be hoped that the British Admiralty's non-magnetic ship *Research* will be put into service as soon as possible after the war as the magnetic survey of the oceans has been much neglected since the loss of the *Carnegie*.

D 18. That further magnetic survey work on land is desirable and that the possibility of using aircraft over both land and sea should be examined with the co-operation of experts of the various types concerned.

Financial summary

The other committees on post-war problems have provided a summary of pre-war and proposed post-war expenditure by university departments. Our proposals do not lend themselves to convenient summary in this way as many of our recommendations involve expenditure by other bodies and much geophysics is done by workers who are attached to departments of physics, geology or mathematics and whose requirements have, therefore, already been included in the reports of other committees.

The only definite figures that we can give are those for Cambridge and for the International Seismological Summary given above.

List of memoranda by members of the post-war geophysics committee

(1) Note on the application of radar to geodesy. (Dr A. O. Rankine)

(2) Development and testing of instruments for geophysical investigations. (Dr A. O. Rankine)

(3) Seismological stations in the colonies. (Dr H. Jeffreys)

(4) The International Seismological Summary. (Dr H. Jeffreys)

(5) Disposal of government-owned scientific apparatus at the end of the war. (Dr E. C. Bullard)

(6) The use of surplus government explosives for seismology. (Dr E. C. Bullard)

(7) Radar and geodesy. (Dr E. C. Bullard)

(8) Proposed programme of experimental work at the Department of Geodesy and Geophysics, Cambridge. (Dr E. C. Bullard)

(9) Post-war ionospheric research. (Sir Edward Appleton)

(10) The systematic recording of cosmic-ray phenomena. (Professor P. M. S. Blackett)

(11) Geomagnetism. (Professor S. Chapman)

(12) Applied geophysics. (Brigadier B. F. J. Schonland)

(*Signed*) A. O. Rankine.

E. REPORT OF THE POST-WAR NEEDS IN GEOLOGY COMMITTEE

The Council at its meeting on 2 March 1944 appointed a committee consisting of:

Professor C. E. Tilley, *Chairman*
Dr E. B. Bailey
Dr O. M. B. Bulman
Professor W. G. Fearnsides
Sir Lewis Fermor
Professor H. G. A. Hickling
Professor A. Holmes
Professor O. T. Jones
Professor H. H. Read
*Dr E. J. Salisbury

* Dr E. J. Salisbury was appointed a member of the Post-War Needs in Geology Committee by Council on 20 April 1944.

Professor A. E. TRUEMAN
Ex officio :
Sir THOMAS MERTON, *Treasurer*
Professor A. V. HILL, *Biological Secretary*

to examine post-war needs in geology.

The committee has met on three occasions.

The committee has reviewed the post-war needs in subjects within the general field of geology and submits the following recommendations to Council.

The recommendations can be classed broadly into three groups :

I. Those concerned with research grants to personnel and grants for the field training of geological students.

II. Those concerned with the establishment of university teaching posts and facilities for training in special branches of geology.

III. Those concerned with research projects or other projects related thereto.

The committee desires to stress the need of more adequate provision of research studentships and senior research grants, both as regards number and value and their period of tenure ; it also directs attention to the urgent need for financial support to geological departments to meet the expenses of field training for geological students during their undergraduate career.

It recommends the establishment of a number of higher grade teaching posts in universities for important branches of the subjects which occupy a major place in the geological teaching curriculum and where it is felt the scope for research is broadest, or for a field, as in the case of vertebrate palaeontology, where there are at present inadequate facilities for advanced training and research.

It has ventured to make proposals regarding specific centres where such posts might be established, selected on the ground that these centres enjoy important facilities by reason of their rich equipment in the materials of research, such as museum research collections (e.g. recommendations E 12, 13).

In drawing up their lists of research projects (recommendations) the committee has dealt primarily with research programmes which must be regarded as additional to the main well-established lines of research that will continue to be fostered as heretofore in the geological schools of universities. The recommendations are therefore only on new projects or projects already begun but the scope of which requires to be widened or the study of which should be more intensively prosecuted. A number of these research programmes will require the active co-operation of workers in other fields if they are to be effectively conducted (e.g. researches referred to in recommendations E 29, 30, 31).

Reference has also been made to the needs of research which will be conducted primarily outside the universities : these concern part of the systematic work of the geological survey and of the fuel survey.

The committee gave preliminary consideration to the research needs of the colonial geological surveys but has made no specific reference to them as it was understood the post-war development policy of these surveys is being dealt with by the Colonial Research Committee.

I. RECOMMENDATIONS CONCERNING GRANTS TO RESEARCH STUDENTS, TO MEMBERS OF UNIVERSITY STAFFS AND FOR FIELD TRAINING OF STUDENTS

E 1. That all students obtaining an honours degree in geology, being suitably recommended by heads of departments, should have the opportunity for post-graduate research studentships and should have facilities to engage in research.

E 2. That the value of research studentships should be at the minimum rate of £220 plus fees a year, the studentships being tenable for three years.

E 3. That provision should be made for the payment of senior research grants of the value of £400 (minimum) to £600 (maximum), the period of tenure of such posts, either at home or abroad, being two years with renewals up to five years.

E 4. That facilities should be made available to enable research workers from overseas to carry out research in British universities.

E 5. That a fund should be available in every geology department for the financing of field studies carried out by students, including travelling costs.

E 6. That facilities (including expenses for travelling and maintenance) should be made available to enable junior members of university staffs to undertake research in the field.

E 7. That heads of departments should have available the services of permanent research assistants whose salary should be from £300 to £400 a year.

E 8. That, where needed, there should be provided in geological departments technical assistants whose salary should be in the region of £250 a year.

E 9. That applications for apparatus, etc., of the value of £250 and upwards be made to H.M. Treasury through the Royal Society.

II. Recommendations concerning the establishment of university teaching posts and facilities for training in special branches in the field of geology

E 10. That a limited number of readerships in invertebrate palaeontology should be established.

E 11. That a post-graduate course in micro-palaeontology should be established in Imperial College, London.

E 12. That provision for advanced training in vertebrate palaeontology should be made at the University of London, at either Oxford or Cambridge, and at one of the universities of Scotland.

E 13. That a limited number of readerships in palaeobotany should be established in the universities of Cambridge, Glasgow, London and Manchester.

E 14. That more adequate provision should be made for training in modern mineralogy by the establishment of special lectureships and by grants for apparatus and equipment.

E 15. That a limited number of readerships in petrology should be established.

E 16. For proposals referring to the field of geophysics in relation to geology, see recommendations E 23, 24.

III. Recommendations concerning research projects and facilities for other projects related thereto :

E 17. That provision should be made for a National Library of Air Photographs on the model of that existing in Canada. Special value is attached to stereoscopic photographs.

E 18. The the completion of the colour printed 1-inch geological map of Great Britain, based on the 6-inch survey, be expedited ; the staff of the Geological Survey being increased for this purpose.

E 19. That revised editions of existing 1-inch sheets should be prepared to incorporate new discoveries.

E 20. That encouragement be given to the occasional interchange of geological staff at universities and the Geological Survey.

E 21. That every encouragement be given to the Fuel Survey to complete their investigation of British coal seams.

E 22. That there should be funds made available for the financing of systematic boring programmes in order to investigate the underground geology of the country.

E 23. That an adequately equipped school of experimental geophysics should be developed at Cambridge ; and that it would be appropriate that the investigation of the behaviour of rocks and minerals under high pressures should be carried out in this institution.

E 24. That the section of applied geophysics at Imperial College be revived and strengthened, and that proposals from other universities or university colleges for similar facilities be sympathetically entertained.

E 25. That provision for the radioactivity determination of rocks, including ocean bottom sediments, might appropriately be made at the National Physical Laboratory.

E 26. That with regard to the age determination of minerals, based on radioactivity, collaboration with the U.S.A. would be adequate.

E 27. That substantial provision should be made for quantitative spectrographic analysis of rocks, minerals and natural waters.

E 28. That there is need for the expansion of quantitative high temperature investigations on petrologically important silicate systems.

E 29. That there is need for the development of research on the physics and chemistry of muddy sediments, including the processes of diagenesis.

E 30. That increased facilities should be afforded for the development of quaternary research.

E 31. That there should be provision for the investigation of the mineralogical and organic features of deep sea deposits. In this connexion it was held that one of the centres for research might be the Natural History Museum.

E 32. That more financial assistance should be available for the publication of palaeontological research.

(*Signed*) C. E. TILLEY.

SUMMARY

	Average pre-1939	Estimated normal post-war year
Numbers of research students	(43)	(75)
Maintenance grants to research students	£5,160	£18,000
Research material for research students	£607	£1,760
Numbers of senior research students	(5)	(15)
Maintenance grants to senior research students	£1,500	£6,000
Research material for senior research students	£130	£550
Number of academic staff (research)	(71)	(91)
Research material for academic staff	£1,186	£2,470
Number of technicians	(20)	(31)
Salaries of technicians	£3,822	£7,500
Number of laboratory boys	(18)	(28)
Salaries of laboratory boys	£1,290	£2,838
Total costs	£13,695	£39,118

Note : Only 50 per cent of those invited replied to the questionnaire.

F. REPORT OF THE POST-WAR NEEDS IN GEOGRAPHY COMMITTEE

The Council at its meeting on 2 March 1944 appointed a committee consisting of:

Sir JOHN RUSSELL, *Chairman*
Colonel Sir CHARLES ARDEN-CLOSE
Professor D. BRUNT
Dr E. C. BULLARD
Vice-Admiral Sir JOHN EDGELL
Professor H. J. FLEURE
Professor A. C. HARDY
Mr A. R. HINKS
Sir GERALD LENOX-CONYNGHAM
Professor J. PROUDMAN
*Dr E. J. SALISBURY
Professor A. E. TRUEMAN
Professor D. M. S. WATSON
Ex officio:
Sir THOMAS MERTON, *Treasurer*
Professor A. V. HILL, *Biological Secretary*

to examine post-war needs in geography.

The committee has met on two occasions and has discussed fully a number of memoranda, drawn up by its members setting forth the directions in which further developments seemed necessary. The committee was of the opinion that some of these subjects would be very suitable for discussion by a larger body such as a Post-War Imperial Scientific Conference. One subject, soil surveys, could be clarified by a small conference of experts available in this country.

The findings of the committee are epitomized in the following recommendations:

F 1. That there be established an Air Photographic Service following the methods of the Canadian National Library of Air Photographs.

F 2. That the African section of the Arc of Meridian 30° E be completed.

F 3. That the maps on the scale of 1/million, all over the Empire, be completed.

F 4. That the various soil surveys made by different groups of individuals in the country and elsewhere be collated and completed, and to this end a small conference be called of representatives of soil science, geology, ecology, forestry and agriculture to consider with the committee what steps could usefully be taken to achieve this purpose.

F 5. That it be considered whether the present methods of making vegetation surveys are adequate; what steps should be taken to complete unfinished surveys at home and in the colonies and dependencies; and what relations should subsist between soil and vegetation surveys.

(Special importance is likely to be attached after the war to the assessment of forest resources and to the study of wild plants of potential value in scientific and technical work. It is suggested that these questions and others arising out of F 4 and F 5 be discussed in a Post-War Imperial Scientific Conference, should one be called.)

F 6. That in view of the urgency of questions of migration and settlement, the following subjects of research receive attention, having special regard to the conditions in the Crown Colonies, Protectorates and Mandated Territories:

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* Dr E. J. SALISBURY was appointed a member of the Post-War Needs in Geography Committee by Council on 20 April 1944.

(*a*) Climate and the well-being of peoples of diverse physical characters. The study of climate especially in its relation to physical, mental and reproductive vigour, as operating over more than two generations.

(*b*) Immigration numbers in relation to prior populations. Diversities of assimilation and adaptation to new environment. Division of labour between immigrants and their descendants on the one hand, and prior population on the other. Division of labour in heterogeneous populations generally. Study of hybrids biologically and economically. All to be considered with particular reference to British settlement in the Crown Colonies, Protectorates and Mandated Territories.

(*c*) Census returns and their possible amplification to secure more data for the above, and data concerning the mobility of immigrants and labour selection among them. Refinement of data concerning rural and more or less urban dispersal grouping.

F 7. That it is important that continued attention be given to problems connected with the changes at present taking place in the earth's surface. (Particular attention is drawn to the desirability of securing stereo-photographs of suitable areas for comparison with similar ones to be taken in the future.)

F 8. That further study of glaciers and ice sheets is desirable, and that the measurement of their thickness by the seismic method is of particular importance.

F 9. That increased facilities be provided for the study of land forms, especially by detailed surveys carried out by geographers and geologists.

F 10. That it is considered that facilities available for the study of the movement of water in rivers and the transport by them of soil and rock are inadequate.

(Work both in the field and laboratory is required. The committee understands that the National Physical Laboratory intends to take up model work in this field and suggests that attention be given to the fundamental processes of erosion and transport as well as to problems of immediate practical importance. In addition, it is considered that useful work can be done by universities and it is suggested that such work be extended. It is noted with regret that some of the work going on before the war (particularly that of Dr Gibson) is likely to cease. It is also suggested that the work of the Ouse Catchment Board, which has been terminated, be published.)

F 11. That the necessity of maintaining the work of the Discovery Committee and of making increased provision for the transport of scientific expeditions by land, sea and air and for their maintenance in the field be a recommendation to His Majesty's Government.

F 12. That there be established a permanent institution with a fixed scientific staff to develop survey instruments and technique, and that such an institution would benefit by close association with the National Physical Laboratory.

(This institution to undertake research for the survey departments of the Empire, but not controlled by one of them.)

F 13. That the extension of hydrographic surveys in deep water and more precise and detailed delineation of the continental shelf is of importance. Particular attention is drawn to the desirability of detailed surveys of physiographically interesting areas such as portions of the Mid-Atlantic Ridge.

(*Signed*) E. J. Russell.

G. REPORT ON POST-WAR RESEARCH IN PURE METEOROLOGY

This report has been drawn up by the Gassiot Committee in answer to a request from the Council of the Royal Society for their views on post-war research in pure meteorology.

The importance of meteorology as a science justifies a much more definite place for it in the universities than it now has, and taking a long view, by far the greatest benefit to meteorological research in this country would be obtained by attracting to the subject a number of suitable young research physicists and mathematicians and providing them with the means by which they could devote at least a part of their time to this research. To attain this end, as well as to create a wider interest in the subject among men of science generally, the first step would be to establish the subject in the universities. Great Britain compares very unfavourably in the matter with other countries. At present there is a Professorship and an Assistant Professorship in Meteorology at London University, a Readership in Meteorology and Astronomy at Aberdeen, a Readership (not permanent) in Meteorology at Oxford, a Readership in Geophysics (not permanent and dealing chiefly with the internal physics of the Earth) and a Readership (not permanent) in Atmospheric Electricity, both at Cambridge. As compared with this, there were in 1935, four large and four small meteorological institutes in Germany—all attached to universities—there were nine in the U.S.S.R., four in Poland, three in France, and three in the U.S.A.

The establishment of meteorology in the universities besides its primary aim of promoting the subject would have a twofold object, firstly to give students of physics a wide general knowledge of meteorology and the main problems of immediate interest ; as a result it may be hoped that a few would be sufficiently interested to wish to take up meteorological research later, e.g., as the subject for a research degree. Secondly, it would provide posts for men who should be able to devote a considerable part of their time to meteorological research.

The teaching of meteorology in relation to the teaching of physics and the housing of the meteorological staff will naturally differ in different universities. In order to give physics students some knowledge of meteorology, there should be a short course of lectures in the honours physics teaching. This method has been found very satisfactory at Oxford and has resulted in some physics students taking post-graduate research degrees in meteorological subjects. At the same time, provision should be made in at least one university for much more advanced teaching of meteorology for those students who, having taken a degree in physics or mathematics, wish to have whole time instruction in meteorology for a year or more, in some

cases with a view to taking up meteorology as a career—such a course is at present available at London University. With regard to the housing of meteorology, in the university, it is very important both that meteorology and physics should be brought into very close contact and also that facilities should be available for experimental and observational work. The fact that this side of the research has, in the past, lagged somewhat behind theoretical research in this country is no doubt due, in part at least, to the lack of opportunity for practical work. The close association of meteorology and physics in a university will both help the meteorologists and will bring meteorological problems to the notice of other physicists. It might be no disadvantage if a lecturer in meteorology were also a lecturer or demonstrator in physics. Meteorology is a branch of physics, and it is important that students should have a good knowledge of physics before they turn their attention seriously to meteorology.

There will be several problems which are unsuitable for research by the necessarily small meteorological staffs at most universities, and a suggestion for a Meteorological Research Institute has already been put forward. Such an institution would serve a very useful purpose. It would, of course, be quite separate from any central research station of the Meteorological Office and their functions would not overlap since the Meteorological Office station would naturally be more occupied in applied meteorology and the Research Institute in pure meteorology though possibly with a practical application. The Research Institute might conveniently be attached to a university—the professor of meteorology being director of the Research Institute. Before the war, London University (Imperial College) had planned to establish such a research station, and it would probably be wise to concentrate on this plan in the first instance. The Society should do everything possible to encourage this scheme.

Turning now to the actual programme of research which the Royal Society should particularly encourage immediately after the war, there is no doubt that the question of the thermal radiative equilibrium in the upper atmosphere (which it has been asked to foster by the Air Ministry) should have the first place. This naturally includes many allied questions such as :

(1) an extended survey of atmospheric ozone over the globe.

(2) further studies of the absorption spectra of atmospheric gases.

(3) composition of the air up to the greatest heights possible with particular reference to H_2O, O_3 and He (the latter because of its bearing on the diffusive separation of gases). . . .

(4) exploration of the temperature at very great heights by means of air waves in all parts of the world to obtain further knowledge of :

(a) the variation with latitude.

(b) annual and diurnal variations.

(c) conditions at the major centres of high and low pressure.

(d) variations—if any—with weather conditions in the lower atmosphere.

(e) variations with changing ionospheric conditions.

(5) a study of solar variation and the absolute value of the 'solar constant' together with the reflection of solar radiation from clouds, and land and sea surfaces.

The Royal Society would naturally wish to foster research on any suitable branch of meteorology, and there is little object in drawing up a list of possible subjects for research which would be almost endless but a few of the more important which seem suitable for research at universities are added below :

(1) The general question of the formation of cloud and rain ; the number and size distribution of cloud and rain drops ; the number, size distributions and composition of atmospheric condensation and sublimation nuclei at all heights and their influence on cloud formation.

(2) The electricity of thunderstorms.

(3) Application of the propagation of radio waves to meteorology.

(4) Absorption and scattering of light in the atmosphere.

It is hoped that there would be close co-operation between the research workers at the universities and the Meteorological Office—Air Ministry. It might be possible to arrange at times for one or two suitable members of the staff of the Office to be given leave of absence for a year or two for work at the proposed Research Institute. Many researches are likely to require the use of an aeroplane, and it is much to be hoped that the Air Ministry may be able to afford research workers at the universities or the Research Institute facilities for work in the air in suitable cases. Such collaboration would be very necessary for progress.

Meteorology requires international co-operation more than most sciences, and this country should take an active part in international organization such as the I.G.G.U. It is very desirable that funds should be available for making observations abroad when necessary.

The main conclusions are therefore that the Society should particularly encourage:

(1) the development of meteorology at the universities.

(2) the establishment of a meteorological research institute.

(3) the programme of work on the thermal radiative equilibrium of the upper atmosphere which the Committee already has in hand.

(4) the continuation of active participation by Great Britain in international meteorological work.

(*Signed*) G. M. B. DOBSON.

H. REPORT ON POST-WAR RESEARCH IN OCEANOGRAPHY

The sub-committee for oceanography of the National Committee for Geodesy and Geophysics met at the rooms of the Royal Society on 1 March and 26 May 1944, to discuss two proposals which had been referred to it by the chairman of the National Committee for Geodesy and Geophysics.

Proposal A—THE ORGANIZING OF A POST-WAR OCEANOGRAPHICAL EXPEDITION.

This proposal arose from a feeler put out by Professor HANS PETTERSSON, of Oceanograpfiska Institutet, Goteborg, that Great Britain should participate with Sweden in an expedition in the North Atlantic after the war.

Proposal B—THE ESTABLISHMENT OF A NATIONAL OCEANOGRAPHICAL INSTITUTE IN GREAT BRITAIN.

This proposal emanated from a suggestion made to the Scientific Advisory Committee of the War Cabinet by Vice-Admiral Sir JOHN EDGELL at about the same time as a similar proposal was made elsewhere by Dr J. B. TAIT in a memorandum numbered D.C. 969, and entitled *Memorandum on the significance of scientific research in planning for post-war reconstruction of the fishing industry*, dated 12 December 1942.

Since A and B are to some extent complementary, they have been set out as a preamble to the report in order to clarify it.

2. PROPOSAL A was examined and discussed at the meeting held on 1 March 1944 and the opinion of the sub-committee is that it would be extremely difficult to launch an oceanographical expedition before the cessation of hostilities in all theatres.

In discussing the Swedish project, it was apparent that an expedition confined to only two countries would almost certainly be parochial in its outlook and programme.

A more ambitious expedition should be organized, though at a much later date, and whilst Sweden should properly be asked to participate, the known interest of other nations should not be ignored ; in particular, the United States of America should be invited to collaborate, whilst Norway, France and other countries might also wish to take part.

The organization of an expedition into the North Atlantic might, with advantage, wait upon the inauguration of a National Oceanographical Institute, if this should materialize, and the institute might be charged with the task of drawing up a programme of the work to be undertaken and recommend the area or areas to be investigated in consultation with the oceanographical offices of participating nations.

3. PROPOSAL B was discussed in detail at both meetings of the sub-committee, which is strongly in favour of setting up a National Oceanographical Institute for Great Britain. It was further agreed that the provision of a research vessel was essential, that she should be of sufficient tonnage and endurance to permit of extensive voyages and prolonged periods at sea, and should be kept permanently in commission.

4. SEAT. The interest of Liverpool University in the science of oceanography is well known and taking all the factors into consideration, the sub-committee recommend that Liverpool should be the home of the institute. Their reasons for this are that the port of Liverpool is a suitable and convenient base for a research vessel, that there is a Department of Oceanography at the Liverpool University, that the Liverpool Tidal Institute is housed nearby.

5. HOUSING. The sub-committee consider that the institute should be properly and adequately housed in a building equipped with offices, laboratories and store rooms, and that generous provision should be made for instruments and scientific equipment.

6. RESEARCH VESSEL. With regard to the research vessel, it was thought that a suitable craft of from 800 to 1,000 tons could probably be obtained from the Admiralty on the cessation of hostilities. The particular class of vessel cannot be decided on until a careful study of the plans has been made and a small sub-committee is going into this matter, but the essential requirements are considered to be economy of personnel and performance, sea-

worthiness, long endurance, ample deck space and above average stability. The vessel should be oil burning. The average annual cost of the research vessel would, it is thought, be in the neighbourhood of £35,000.

In considering the provision of a research vessel, the sub-committee had in mind the work which is being done by the ships belonging to the Ministry of Agriculture and Fisheries, and the Fisheries Division of the Scottish Home Department, and are of the opinion that the work should be continued without prejudice to the ocean-going research vessel required to undertake the work of the Institute.

7. WORK. The work to be undertaken by the National Oceanographical Institute is set out in the attached Appendices A and B, which were prepared by a sub-sub-committee. These annexes are not necessarily complete in every detail but are thought to cover the ground generally and by implication to include all such matters as should be the legitimate concern of the institute.

Appendix A is a generalized statement, and Appendix B a particularized one specially prepared for the National Committee for Geodesy and Geophysics, the Council of the Royal Society, and the Scientific Advisory Committee of the War Cabinet ; it is to be noted that the list of bodies with which the institute could profitably collaborate in the United Kingdom does not pretend to be final, and that no mention is made of foreign institutions with which contact would certainly need to be maintained.

8. STATISTICS. It is most desirable that the institute should have expert statistical advice at its disposal, and that a comprehensive index of sources of all necessary data should be compiled ; in so far as statistics are concerned, it seems probable that the Liverpool Tidal Institute will be able to give all assistance necessary and on all counts it seems highly desirable that the Tidal Institute should become absorbed by the Oceanographical Institute, since it will be directly interested in the work of the latter, and able to assist by placing computers at the service of the oceanographers.

9. INSTRUCTION. The question of teaching students was debated and it is recommended that this should be developed in conjunction with the universities and in collaboration with them. Moreover, it is hoped that Liverpool University will be able to participate actively in this part of the work.

10. STAFF AND SALARIES. In considering the staff required for a National Oceanographical Institute, it was thought that its composition should be designed to permit of future expansion and

that the biological aspect of oceanographical investigations should not be neglected. The sub-committee consider that the appropriate staff, additional to the staff required for tidal purposes (in continuation of the work of the Tidal Institute) should be as follows :

Director . . .	(£1,150–£1,500)
Chief Chemist . .	(£680–£800)
Chief Physicist . .	(£680–£800)
Marine Biologist . .	(£650–£750)
Meteorologist . .	(£350–£580)
Geophysicist . .	(£350–£580)
Average cost of Senior Staff. Total	£4,435+Civil Service Bonus

1 Mechanic . .	(£200–£300)
5 Technical Assistants .	(£150–£250)
2 Laboratory Assistants .	(£100)
2 Computers . .	(£120–£200)
1 Marine Superintendent	(£585+pension)
1 Office Staff . .	(£350–£515)
1 " " . .	(£160–£350)
1 " " . .	(£160–£350)
1 Librarian-Bibliographer	(£250–£400)
Average cost of Junior Staff. Total	£3,622+Civil Service or Industrial Bonus.

All salaries should be on the F.S.S.U. or some equivalent scheme. Add 10 per cent to cover this and the total average salary bill would be about £8,960 per annum, plus Civil Service or industrial bonus.

11. Upkeep. It was considered that an annual charge of about £3,000 should be allowed for the upkeep of the building, services, gear, stores, apparatus, etc., which, together with the costs connected with running the research vessel, paying the crew, etc., would bring the total annual cost of the institute to about £46,500.

12. Governing Body. The sub-committee recommends that the institute should be governed in a similar manner to the Department of Scientific and Industrial Research, and that it should, from time to time, publish papers of interest to oceanographers and as a result of its labours both ashore and afloat.

The governing body should be composed of representatives of Government Offices, the Learned Societies and the Universties, and an Executive Board or Council should be set up who would be mainly responsible for the day-to-day affairs of the institute.

The following are suggested to form the governing body :

Representatives of the Royal Society . .	3
The Admiralty	2
(of whom the Hydrographer should be one)	
Minister of Agriculture and Fisheries . .	1
Colonial Office	1
Meteorological Office	1
The Universities	5
(of which one to be from Liverpool and not less than one from the Scottish Universities)	
Fisheries Division of the Scottish Home Dept.	1
Geological Society	1
Royal Geographical Society . . .	1
Royal Society of Edinburgh . . .	1
Royal Astronomical Society . . .	1
Marine Biological Association . . .	1
British Museum (Natural History) . .	1
Department of Scientific and Industrial Research	1
Challenger Society	1
Mersey Docks and Harbour Board . .	1

It is assumed that some members of the governing body would represent more than one of the above departments, societies and universities.

(*Signed*) J. A. EDGELL.

MORNING SUBJECT (n)

DISCUSSION OF AN ALL-AFRICAN ORGANIZATION FOR THE CO-ORDINATION OF SCIENTIFIC WORK WITHIN THE AFRICAN CONTINENT

Steering Group

Chairman—Professor B. F. J. Schonland, F.R.S.

Recorder—Mr E. Boden

Mr C. V. Carstairs
Mr J. K. Chorley
Mr R. Daubney
Lord Haley
Dr P. J. Du Toit

Report

The discussion was designed to give an opportunity to the delegates from South Africa to put before the Conference a proposal that the African Continent, south of the Sahara, should be considered as a regional area for long range fundamental research.

It was pointed out that the future development of the African Continent would depend on the intensive application of scientific research, and that while there was no case for the regionalization of short-term research, the long term and fundamental problems would profit by being tackled on an all-African basis. It was generally agreed that the existing artificial political boundaries had no significance in the investigation of fundamental problems and were in fact a stumbling block in the way of such investigations. The solution of fundamental African problems would require men and equipment of the highest quality. Investigations on the appropriate scale could not be conducted by any one of the African territories alone.

In the field of veterinary science most of the basic and most serious problems were common to all the African territories. Rinderpest, East Coast fever, horsesickness, foot and mouth disease, 'lumpy skin disease' and trypanosomiasis were quoted as examples and a case was made for the extension of the work at the existing institutes of Onderstepoort and Kabete to take more responsibility for the solution of problems of an all-African nature.

Though many agricultural problems must continue to be treated on a local scale, soil conservation and plant genetics and breeding were two typical cases where much more could be achieved by broadening the territorial scope of the investigations. The Botanical Herbarium in Pretoria could well be extended to serve the whole of Africa.

The malnutrition of the African peoples and the tropical diseases peculiar to the African Continent were mentioned as examples of medical problems that would profit by being investigated on a regional basis.

The setting up of a series of regional geological bureaux was proposed as necessary for the better development of Africa's mineral resources. It was noted that the relatively highly developed geological services in South Africa could be of great benefit to the Continent of Africa as a whole.

Palaeobotany was mentioned as a further field where co-ordinated

study would be of benefit both to Africa and to other continents, such as Australia, where similar conditions existed.

General African climatology and long range forecasting were cited as further examples of studies in which collective action would prove advantageous.

It was realized throughout the discussion that co-operation in the proposed regional plan among the various African territories should be on a voluntary basis. In order to ensure that scientific workers of the highest qualifications would be encouraged to participate, adequate financial support should be provided for the scheme.

Recommendations

1. The Conference considers that there is a growing need for the development of long-term fundamental research dealing with African problems on a regional, as distinct from a territorial, basis.
2. To meet this need there should be formed at an early date a Commonwealth African Research Committee with the following terms of reference :

    (a) to examine and put forward proposals for the centralization of fundamental research in African problems on a regional basis.

    (b) to plan such developments ahead so as to ensure the necessary financial support and the training of the specialist staffs needed.

    (c) to advise the governments concerned through the appropriate authorities on matters of regional development and co-operation in fundamental research.

3. The field of the Committee would in the main cover activities south of the Sahara, and foreign states with territories in this portion of Africa should be invited to be represented as observers.

DISCUSSION

No verbatim notes of the discussions were taken at the time of the Conference ; in consequence the summaries of verbal contributions only of those delegates and guests who kindly submitted their notes are printed below.

Dr. E. H. Cluver

In the field of medicine fundamental research is required on four subjects to give the applied scientists in southern Africa the data needed to deal with malnutrition, tropical disease, physical environmental hazards and silicosis.

The nutritional problem to be tackled in Africa is the provision of cheaply raised protein-containing and protective foods with which the natives starch diet can be balanced. This requires vitamin, mineral and protein assays of all our foods grown under great varieties of conditions. The aid of the agriculturist is obviously needed. He must experiment with varieties of crops and fertilizers under varying conditions so that the cheapest balancing foods can be arrived at.

Tropical disease causes much disability in southern Africa. We need many more entomologists to study the insect-borne diseases. Studies must also be prosecuted with a view to relieving the extensive parasitization of African peoples with intestinal worms and schistosomes. A tropical disease research institute located at Salisbury in Southern Rhodesia could do very useful work. It would be sufficiently near the regions where these diseases are produced while being itself in a salubrious atmosphere. The southern universities would welcome such a centre where their postgraduate students could read for doctorates.

The adverse physiological factor to be contended with is the low cooling power of the atmosphere over large areas of the tropics and in the deep mines of the Witwatersrand. In both cases the evil effect of high atmospheric temperatures is intensified by humidity. In the mines the water is deliberately added to the air during the process of drilling to combat the liberation of fine silica dust.

Silicosis is much the most serious hazard of gold mining in the Transvaal. Careful selection of candidate miners and the limitation of dust formation has greatly reduced the incidence of this condition.

Sir Lewis Fermor

Sir Lewis Fermor said that although the Chairman had asked speakers to confine their remarks to fundamental problems, most of them had been unable to avoid discussing applied science. This was probably because research in fundamental science so often produced results of benefit to mankind. And this very fact alone was a powerful plea for action in support of Professor Schonland's proposal.

He (Sir Lewis) was not without personal knowledge of Africa as he had spent about a year in East and South Africa with visits to the Rhodesias; so he felt justified in joining in this discussion.

Although Dr Nel had not mentioned it, yet in the geological sphere there had already been international co-operation as a result of the International Geological Congress of 1929 in South Africa and the Rhodesias. As a joint effort with the geological surveys of the Portuguese, Belgian and French territories, a geological map of Africa had been compiled, and in addition a dictionary of geological nomenclature for Africa had been published.

Geological surveys were maintained for economic ends, but these ends could be fully attained only if the fundamental work of preparing geological maps was systematically carried out. He would now mention a geological problem affecting several African territories. This was the origin of the great Rift Valley that traversed Africa from the Red Sea through Central Africa almost to South Africa. A systematic survey, geological and geodetic, of the belt affected by this great system of fractures would be an exercise in fundamental science, requiring the co-operation of several countries. But it would inevitably bring economic or applied benefits, information on water supplies, mineral deposits and engineering problems.

Apart from international agreement to establish and finance research institutions there was another, very simple, method by which the scientists of Africa would collaborate. They might take a leaf from the geologists' notebook and organize periodic, even annual, conferences for each science, in each country in turn.

Mr A. Glendon Hill

Mr Glendon Hill stated that, like Dr Storey, he found what he wanted to say had already been said by earlier speakers. However, there was one point he wanted to labour—the supply of research officers. As one who had been connected with fundamental research in East Africa for some years he felt sure that the success of any Pan African scheme for fundamental research depended almost entirely on recruiting the right kind of research worker. Unless the terms of service for Colonial research workers were modified he thought it would be increasingly difficult to obtain first-class research workers for our colonial dependencies.

Sir David Rivett

Sir David Rivett (Australia) in welcoming the proposed African Scientific Research Council suggested that, as Australia shared with Africa so many very significant scientific problems, it would be a fine move towards the Commonwealth co-operation so frequently advocated in Conference discussions, if a seat at the new Council table were made available to an Australian, implying the right for a suitable scientist to share in any technical discussion of a matter of common interest. Reciprocal freedom to share in Australian deliberations he was sure would be gladly accorded by Australia to representatives of African science. Dr Schonland later accepted the suggestion.

Dr H. H. Storey

Dr H. H. Storey referred to the existing regional organization of agricultural research in respect of six East African territories. He thought that East Africa would welcome any practicable steps for securing closer co-ordination of research effort throughout the wider area of Africa. But, in view of the very limited financial and other resources of East Africa, he considered that its major effort would inevitably go into applied or objective fundamental research. He hoped that schools of true fundamental research would arise and would receive every encouragement ; but he would prefer to see them emerge in response to recognized needs or around proved leaders of research. Under these circumstances the research would be likely to start with, and to maintain the confidence of the people and governments, from whom ultimately the funds must come.

Dr. H. Hamshaw Thomas

Dr. Hamshaw Thomas said that he wished to draw attention to the need for establishing in South Africa an institution for research in Palaeobotany. The correlation of the post-Devonian strata over the greater part of Africa south of the equator, and the determination of their age depended very largely on the use of fossil plants. The organisms found were generally distinct from the types found in the Northern Hemisphere and they were still imperfectly known. The late Professor Sir Albert Seward, Dr A. L. Du Toit and the speaker had carried out investigations on the South African fossil flora, but full time research was needed both on the larger remains and the microflora. It was very uneconomical to attempt to do such work in England, and an institute with accommodation for large collections and a good library was needed at some suitable place in Africa, preferably in South Africa where the greatest variety of forms had been hitherto obtained. If such a centre were established and staffed with a few active investigators, results would certainly be obtained which would assist the work of geological investigation and the development of coal-producing areas. Such work would also be of considerable value to geology in Australia where the fossil plants were very similar and there was also a lack of trained investigators at the present time. Indian geologists would also be interested, for palaeobotany was a subject now receiving much attention in India and research was being actively carried on. He felt sure that this suggestion would have the support of all geologists working in Africa.

Dr. E. B. Worthington

Dr. E. B. Worthington welcomed the Chairman's remarks in putting further discussion on a different level. He suggested that, while the conception of a region consisting of Africa south of the Sahara was sound in many ways, the links with North Africa should not be overlooked particularly the Nile on the east, and French culture on the west, both of which connect across the desert belt. The Nile should give a common interest to eight countries which share its catchment area, and often research in one of those countries is more important to another country lower down the river than to itself. Thus the climate of East Africa

and soil erosion in Ethiopia have been responsible for the whole civilization of Egypt, and the time has come when long-term water storage at the head of the Nile is necessary. He instanced the rôle of swamp vegetation as a subject for fundamental research needed in Uganda and the Sudan, but with far-reaching implications to Egypt on account of its effects in transpiring a large proportion of the total water supplies available.

Dr. Worthington regretted that there was no delegate from the Anglo-Egyptian Sudan, where he had recently studied scientific problems during a survey of the Middle East. Apart from the northward connexion dependent on the Nile, most of the problems of the Sudan, and also of Ethiopia, are closely linked with those of countries to the south, and therefore should come into any pan-African schemes of research. In the Sudan excellent research is progressing in medical and agricultural subjects and also in education at Bakt-er-Ruda and at Gordon Memorial College. Experience gained in the Gezirah irrigation schemes and in the Zande area is of the greatest importance. He emphasized strongly the progressive attitude which is being adopted in the Sudan in tackling problems which are fundamental to the development of all inter-tropical Africa.

Referring to the contention that fundamental science should be developed by an organization on which all African states are represented, Dr Worthington suggested that there is danger of over-organizing before there is any research. A tradition of fundamental research is needed desperately in Africa, but it will not be built up by co-ordinating committees because it is the man that counts more than the committee. In older countries the tradition has grown up around universities in a haphazard way, and the same should occur in some measure in Africa. There is great scope for introducing fundamental research at the two proposed Colonial universities, in West Africa and at Makerere in Uganda, and also at Gordon College, Khartoum. There are already some good men at these centres, but they must be given better facilities for work. The universities should become autonomous in research, and not have programmes subject to check by the sterile arm of officialdom which may freeze the bud of fundamental research before it has a chance to open.

Some subjects must clearly be organized and stimulated from above, and to those listed by Professor Schonland, he would add hydrology and fisheries. In some biological subjects, however, there is danger in over-centralization and for taxonomic and ecological studies Dr. Worthington favoured regional institutes in East Africa and West Africa in addition to a headquarters in the Union. He would greatly favour a Pan-African Committee for fundamental research, especially if it had funds to expend. He sounded a note of warning, however, that the £1,000,000 per annum available for Colonial research under the C.D. and W. Act was not likely to have much balance for fundamental studies when all the urgent demands for applied research had been met.

FUNDAMENTAL GEOLOGICAL RESEARCH IN AFRICA

By Dr Louis T. Nel, F.G.S.

Introductory

In his paper on 'Africa as a Regional Area for Fundamental Research,' Dr Schonland distinguishes between applied and fundamental research, both of which are necessary for the future development of the African continent. The first type with short-term *ad hoc* objectives is, as pointed out by him, already developing throughout the African continent. The other is of a purely scientific and long-term nature, whose importance unfortunately is still too often underestimated. Regular financial support for fundamental research is really sound investment in that it will furnish the applied researcher with new ideas and techniques the successful application of which will yield rich returns and might be of universal benefit. Fundamental research often lends itself to teamwork, and it should not suffer the restrictions of political boundaries.

The purpose of this contribution to the discussion on regional research is to point out the need also for fundamental research in the field of geological and mineralogical science in so far as it concerns problems of common interest to the African territories. Lines along which such research might proceed are also suggested for consideration.

Fundamental studies in geology and mineralogy which are probably of common interest to African territories, particularly those south of the Sahara, and which it is felt will yield results that eventually will be of great value in the search for mineral materials are grouped for convenience under the following heads : correlation of strata, the age of rocks, mineralogy and geochemistry. The lines of research mentioned here represent some of the possibilities for teamwork. No doubt there are other research problems which have not come to mind or which are bound to arise later, problems which can be most satisfactorily tackled by co-operative effort. Geophysical, spectrographic and X-ray studies to aid geological research are not mentioned here as they will probably be dealt with elsewhere in this discussion.

Correlation of strata

Large areas of country in the African continent are occupied by strata whose correlation and systematic classification have not yet been satisfactorily settled. Nomenclatorial troubles have been experienced as a result and a revision of provisional chronological tables is necessary. Problems of stratigraphic correlation became particularly evident when the preparation of the different sheets of the International Geological

Map of Africa was attempted, and at such conferences of African geologists which were held as a result of the International Geological Congress which met in the Union of South Africa in 1929. Most of the data required for a reliable classification of strata can only be obtained by mapping areas which are still little known geologically. Such mapping need not necessarily be detailed in the first instance. Reconnaissance mapping it seems would serve to show the extension farther afield of formations whose positions in the stratigraphic column have been more or less accurately established and to reveal their relationships to other formations. The geological mapping would be expedited and rendered more accurate if aerial surveys of the regions could be first undertaken and the geologists provided with photographs of the ground. As aerial photographs are also of great assistance to the agricultural sciences and other undertakings concerned with the development of a country conjoint arrangements for aerial surveys of selected areas might be possible.

Although, areally, fossiliferous sediments occupy but a small part of the huge area considered, their detailed correlation depends on the accurate determination of the animal and vegetable remains preserved in them. It has been customary for each individual territory to have such determinations made by specialists of its own choosing. Valuable collections of fossils thus become dispersed to various countries, frequently outside Africa, and the worker who endeavours to consider large-scale correlations is handicapped by his inability to study all these at first-hand. The institution of a central palaeontological institute, founded for the study of African fossils, would be definitely a step forward.

Correlation, which is mainly pure geology, is a necessary preliminary to further geological research, and to scientific prospecting and the efficient development of the mineral potentialities of African territories. It will require close co-operation between the different geological organizations in Africa to ensure its success.

The age of rocks

Closely bound up with the problem of stratigraphic correlation is that of the age of rocks. The absence of fossils in important stratigraphic formations of pre-Karroo age necessitates the utilization of all sources of information such as lithology, petrology and a close study of the field relationships in attempts to correlate them. But correlation based on these factors can be of doubtful value. Additional evidence bearing on their ages has to be sought for to improve a classification which is obviously only tentative at present.

The correlation of non-fossiliferous sediments would seem to be most possible on the basis of the ages of the various igneous masses intrusive into them. A line of research which has been followed and which seems to hold out promise of success is that of determining the ages of igneous rocks by radio-active methods. If their ages are known it will make possible the determination of at least the approximate age of the sedimentary rocks. Further, large igneous masses might contain rocks of differing ages, and it is highly important for purely geological and for economic reasons to test this possibility.

Hitherto, the results obtained were apparently not always reliable. Discrepancies have been noticed in age determinations by means of the radium-lead ratios and helium contents of igneous rocks. In the light of recent knowledge and experience gained in radio-active methods, however, and because of further technical improvements of considerable importance, one confidently anticipates that continued research in this field will yield results of great value to regional geology.

An attempt should be made to interest the various African governments in this piece of research work and to persuade them to place adequate financial means at the disposal of investigators in the various territories and so to enable them to undertake the research in a spirit of collaboration. Opportunities should also be afforded for selected scientists to proceed overseas to acquire from specialists the necessary knowledge and techniques for carrying out the investigations in various parts of the continent, and arrangements made whereby it will be possible for these investigators to consult with one another periodically on the results obtained. The Commission of African Surveys established by the International Geological Congress offered the suggestion at a meeting held in Moscow in 1937 that it might be possible at some future date for South Africa to be the centre of this type of research for the whole of the African continent south of the Sahara.

Mineralogy and chemistry

Advances made in mineralogy and geochemistry during recent years have opened up new fields not only of fundamental but also of applied research. The application of conclusions of mineralogy and geochemistry have already been proved of great value in deciphering processes of mineral migrations and formation, in problems of raw mineral materials, of their resources and utilization in industry, and of finding substitutes for those in short supply. New methods of surveying and prospecting have been provided which have led to the successful discovery of new deposits. In mining practice too the introduction of scientific mineralogical methods will be conductive to more efficient following and extraction of ore.

These two sciences offer a wide field for research, achievements in which will materially assist further industrial and economic development and progress. Trace elements of ore minerals, the distribution of uranium, thorium and other rare elements in the earth's crust and their extraction from disseminated ores, the possible correlation of igneous rocks by means of their trace elements, the distribution of toxic elements in rock formations, the application of spectrographic and X-ray diffractive methods in the study of mineral substances, changes in mineral composition leading to granitization and the utilization of considerable natural resources which lie dormant, are a few examples that come to mind of the problems whose study has interested mineralogists and geochemists, and whose solutions have great practical possibilities. They are indicative too of the type of problems which arise in this field of research that is not confined to one country alone, problems which will respond to collaboration between research workers not only within the sphere of mineralogy and geochemistry but in other fields of scientific research as well. New methods of

research of course have not eliminated the necessity of descriptive mineralogy and the continuation of painstaking accumulation of mineralogical data which is still fundamental.

The information in the following paragraphs on mineralogical and geochemical aspects was furnished by my colleague, Dr B. Wasserstein, Senior Mineralogist to the Geological Survey.

Minerals and rocks are not distributed according to international boundaries although certain types may show an areal concentration. A similarity exists between the geological formations found in the various territories in the southern half of Africa. There is thus a sound basis for a southern African division for mineralogical and, of course, geological research.

Any joint geological investigation or any regional investigation by geologists should lead to either the centralizing of the mineralogical investigations of samples or, if not feasible, to a co-operative effort on behalf of the mineralogical staffs. This would enable a free interchange of information without the delay that intervenes before publication can be effected.

A mineral study which could even extend to beyond the regional confines envisaged and which embraces fundamental and applied research, could be undertaken on the so-called 'titaniferous magnetites.' The utilization of such ores as sources of titanium, vanadium and iron seem possible. South Africa possesses very large deposits of this ore and preliminary work has indicated that several types occur which would possibly respond differentially to metallurgical processes that await development. Another example could well be the comparative study of the chromite ores of Southern Rhodesia and Transvaal ; or, the study of the euxenite minerals in the Union of South Africa and in Swaziland. Other mineral studies could embrace tin mineralization, iron ores, tantalum minerals, etc. Here only economically important minerals have been listed, but of course the whole mineral kingdom is available for such investigations, but these should then be systematically planned in order to give results which will mutually benefit all in reasonable time.

In mineralogy, techniques are continually being improved upon and new ones are being developed. The training of personnel by a sort of 'refresher' course becomes desirable and should be organized. A system of interchange might perhaps be fostered so that scientists or technicians could visit laboratories which provide facilities for learning the one or other method or technique of research.

The Mineralogical Laboratory of the Geological Survey could adequately participate in any regional scheme. In practice this has happened on a small scale. Geologists and mineralogists of neighbouring territories have been assisted in the identification of minerals and rocks, and the preparation of material for study, or they have availed themselves of the Laboratory's facilities.

Geochemistry, which is closely linked with mineralogy, is primarily concerned with the migration and distribution of chemical elements in the lithosphere. That geochemical research provides a better understanding of rock and mineral formation, and that it has been possible from a knowledge of geochemical rules to forecast the distribution and accumula-

tion of various elements in the search for minerals, can be accepted. How much more can be accomplished only the further accumulation of facts will establish.

There are many problems of a geochemical nature which concern the development of more than one of the African territories. A regional scheme could pose the problems to be tackled by co-operative effort. Some geochemical studies carried out by investigators in South Africa on the distribution of trace elements may serve as a guide.

Prominent among these were the areal distribution of boron in manganese ores and in iron ores, the determination of the minor constituents of galena ores and the proof of the absence of vanadium in them in the Union, and a geochemical survey of fluorine in rocks frequently drilled for underground water supplies. It is certain that the determination of the minor constituents of gold, cassiterite and other ores would yield results of interest to the scientist, the metallurgist and the mining man; while, as in the case of fluorine, the examination of rocks and soils for small quantities of the toxic elements molybdenum, chrome and cobalt would yield results of practical value to the agriculturist and others. Attempts at correlation of granites and lavas have not progressed sufficiently in South Africa to make any comment but some work at the Government Metallurgical Laboratory, based on Hahn's method of age determination by rubidium, is showing promise on selected minerals.

A regional approach to geochemistry would enable more diverse and more suitable suites of rocks and minerals to be examined, and the results would approach completion. Such results are fundamental to the concepts of mineral formation and geological processes, and doubtlessly will find application in technology as is already confidently claimed in some quarters.

Regional Organization for Geological Research

At present there is no organization with the requisite authority to ensure that a regular correlation is undertaken of the knowledge obtained from the various States in Africa and which could also arrange, when necessary, for geologists from one State to study mineral occurrences in another. Dr Haughton, Director of the Geological Survey, favours closer collaboration between the various Departments of Mines within the Commonwealth in order that a fuller knowledge of available mineral resources therein may be reached in the most efficient manner. Particularly should we strive for such collaboration to be effected between the African territories of the Commonwealth in view of the fact that the geological features associated with mineral occurrences in a very large part of the continent are not limited by geographical or political boundaries but are common to a number of such territories. For consideration at this Conference he therefore suggests the following type of organization which, if it is permitted to function properly, would assist in advancing our knowledge of the Commonwealth's mineral potentialities.

1. There should be organized, where they do not already exist, a series of regional geological and mineral information bureaux, sponsored by the interested governments. One such bureau might have as its field the geologically rather similar territories of the Union, South-West Africa,

Bechuanaland, Swaziland, Basutoland, both the Rhodesias, Nyasaland, Tanganyika Territory, Kenya, Uganda, Zanzibar and Mauritius.

2. The duties of such a bureau would be to receive from and disseminate information to similar bureaux in other parts of the Commonwealth ; to arrange for periodic meetings between representatives of its constituent members for the discussion of common problems ; to arrange, as far as necessary, visits by official geologists and mineral investigators from one territory to another or from one regional area to another; and generally to support and stimulate co-operation and collaboration.

3. Because of the delay which normally exists in the publication of information, the Bureau should be authorized to obtain and disseminate unpublished results of investigations confidentially, either in full or in summary form as may be decided by the government contributing the information to it.

4. A Regional Bureau would be financed by contributions from the supporting governments, to an extent that would be mutually decided. Details of its organizational arrangements might be similar to those of the Imperial Agricultural Bureaux which have operated so successfully for a number of years.

5. A Regional Bureau supported by several governments of varying financial resources might be able to assist the less fortunate contributors to the organization by arranging for certain investigations involving laboratory work to be carried out in a properly equipped and capable institution at far less cost than would be involved if the contributor in question had to finance such an institution in its own territory. For example, an ore-dressing problem from, say, Kenya might be investigated in the Union's Government Metallurgical Laboratory ; or problems involving geochemical or quantitative spectroscopic research might be undertaken by the Union's Council for Scientific and Industrial Research in its laboratories.

6. The staff of such a Bureau would not, at any rate for a time, need to be numerous. A director of standing would be required, together with one or two scientific assistants. Clerical staff would be necessary and office accommodation.

7. Because of the Union's present position of being *primus inter pares* in the field of southern African geological and mineral surveys it is suggested that, in spite of possible geographical disadvantages, Pretoria should be the headquarters of the Regional Bureau serving the territories named in section 1 above. The necessary office accommodation might be provided, at least for a time, by the Union Geological Survey or by the C.S.I.R.

In stating that he does not know what the reaction of the Conference is likely to be to this or a similar set of suggestions he points out : ' It is clear that none of the British Africa's territories can afford to ignore the scientific and technical results which are being and will be obtained from its fellows and that each one stands to gain by effective co-operation with the others. What applies to the African territories applies to the other constituents of the Commonwealth. I visualize a central organization ; but, in order that it may not be too unwieldy a growth and too far removed in the first instance from contact with local conditions, I favour the organization of regional bureaux as a link between local units of the far-flung Commonwealth and the central body at its heart.'

REGIONAL ORGANIZATION OF AGRICULTURAL RESEARCH IN SOUTH AFRICA

By A. R. Saunders, D.Sc.(Agric.)

The cardinal importance of the agricultural industry in the development of Southern Africa, especially as regards the provision of adequate food of the right kind for the people and of raw materials for the manufacturing industries, compels a much wider outlook than that imposed by the limits of national boundaries. Co-operation in research enterprise is rapidly assuming international proportions and the time has come for Southern Africa to take stock of its position in relation to the major problems of agricultural research and to find the best means by which the available forces can be applied towards their solution.

Co-operation can be effected in many different ways, but the main issue might be carried further and an investigation instituted into the possibilities of organizing research on a regional basis with the concentration of certain fundamental aspects or phases at selected institutions.

The chief advantages would be those of greater economy and efficiency through the avoidance of unnecessary duplication and through the creation of better facilities for specialized phases of work at chosen centres. Few experiment stations are able to have the staff and equipment for all phases of agricultural research, and on the smaller stations a large proportion of the time of technical staff is usually occupied with ordinary routine duties. The establishment of leading centres of research would automatically also have the beneficial effect of ensuring close co-operation and full interchange of views and information in the particular field of investigation.

By the nature of things such regional organization has its greatest need, and will yield its most fruitful results, in fundamental research. Owing to differences of climate and soil, investigations on the applied side have more often than not to be repeated at widely distant points or even within a limited geographic area.

Although a vast amount of scientific information is of universal benefit and application, there are many phases in regard to which we in Southern Africa virtually have to build up our own agricultural science. To this end we need to bend all our energies if we are to keep pace with the demands of modern agriculture and make our contribution to the store of world knowledge.

Another matter is the training of research workers. Not all young men fresh from university are fitted to undertake responsible research. Their association, before being placed on their own, with a research institution dealing with the problems of their future activities can only serve a useful purpose in suggesting the right approach and the local or regional point of view.

SPECIFIC FIELDS OF RESEARCH

The suggestions which follow are based largely on discussions which the writer was privileged to have with his colleagues in the Union Department of Agriculture, to whom he gratefully acknowledges his indebtedness.

Conservation of soil and other natural resources

Of paramount importance and deserving of attention on an international plane is the protection of the main watersheds and river basins. The watershed might be in one State while the rivers which flow from it pass through the territory of another. The wide implications of the problem are obvious, and require no detailed discussion in this brief commentary.

The impact of Europe on the African soil has had repercussions which have shaken the very foundations of native society. New ways of life for the African have inevitably created new difficulties. Conservation farming is as much a philosophy of rural life as a matter of agricultural technology. A study of human relationships, with a view primarily to adjusting native custom to the needs of the times, is therefore as important as technical details of farming policy.

Since soil conservation is basically a question of correct and good farming it relies on many branches of research for its guidance. Much of this research can be carried out only in particular areas or even localities, but certain more scientific aspects could well be centred at a few main institutions. Amongst these are soil microbiological investigations, physico-chemical research, the erodibility of different types of soil and the factors which affect it, the influence of type of cover on erosion, carbon relationships, mechanical and cultural methods of combating soil erosion, and a whole range of related matters.

The list of problems is in fact a long one and some of the issues involved cannot yet be clearly defined. Moreover, the distinction between fundamental and applied research is in many instances difficult to draw. In the latter field the scope is broad, branching even into the economics of agricultural production, but the greater part of the work is concerned with local problems. Thus the management of the veld to preserve the vegetal cover, and the types of crops and animals produced will depend upon climatic factors, while the general type of farming practised is subject to economic feasibility or pressure.

Pasture research

One of the main pillars of conservation research is the study of pasture management, of which the basic aim is the conservation of vegetation, soil and water supply. The writer holds the view that while a great deal of soil and water loss in Africa must be ascribed to wrong methods of arable farming, the limitation of run-off and the control of erosion is in compass, if not in character, essentially a problem of pastoral farming.

Pasture research work is by nature such that very little of it can be centralized. It would appear as if the immediate object at least should rather be co-ordination on a regional basis and an extensive scale, leading in due course to a careful correlation of findings and to concerted action.

Furthermore, the work should go hand in hand with other studies of

biological relationships, for the consequences of disturbing the balance of Nature cannot always be foreseen. To cite but one example—the efforts which are now being made to destroy the tsetse fly. This manifestly seems a step forward but there are those who fear the ultimate result of success more than the ravages of the insect, unless timely measures are taken to protect the natural resources of soil and vegetation which are now, in a sense, being protected by the presence of the fly.

Research on soil chemistry and physics

In the final analysis all agricultural production, whether pastoral or arable, rests on soil productivity. In Southern Africa the process of production has hitherto been predominantly exploitative and thus destructive of the existing natural resources. In the past the full consequences of this policy have to some extent been avoided by shifting cultivation and grazing areas and allowing depleted soils to regain some form of natural cover and restore their fertility. Under the stress of increasing population this method is no longer possible to apply ; besides, in the light of modern agricultural requirements it is too slow and uneconomic.

Southern Africa has its own characteristic soil problems, amongst which the following are a few of the more clearly understood examples :—

(a) widespread deficiency of available phosphates,
(b) extremely rapid oxidation of organic matter in cultivated soils due to high soil temperatures and other contributory factors, and
(c) an apparently rapid deterioration in the structure of most soil types when subjected to cultivation.

The phosphate problem involves such questions as : (i) the mechanism of fixation of P_2O_5 and its relation to the natural soil processes in various soil and climatic zones, (ii) the maximum fixing ability of soils of various types and a clearer understanding of the colloidal fraction responsible for fixation, and (iii) the most suitable forms of phosphate fertilizer and methods of application.

Oxidation of organic matter and collapse of soil structure appear to be closely inter-related. Loss of structure is followed by a sharp decline in productivity and by enhanced susceptibility to erosion. The movement under natural conditions of soil colloids, both organic and inorganic, and of salts and bases, and the changes brought about by cultivation, are bound up with problems of fertility, microbiology, structure water-relationships, soil physics and geochemistry, on all of which information is seriously lacking.

The little work which has so far been done in Southern Africa has been sketchy and unco-ordinated and is in the main the result of individual effort. As a first step an extensive survey is required of the main soil types and their relation to climate, followed by an intensive inquiry into the processes of soil formation and degradation. Such investigations could be fruitfully guided, encouraged and stabilized by an authoritative central research organization or institution, with experiment stations strategically placed on the main soil types in representative climatic areas.

AGRONOMY

Agronomic investigations are, for obvious reasons, mainly of a local character, yet there is a considerable amount of technical investigation the results of which could be of relatively wide application. Soil management, utilization of moisture, the influence of manurial treatment on the soil as well as on crop yield, microbiological relationships under different crops or cropping systems are some of the questions which require penetrating investigation.

Hitherto far too little attention has been paid to the relationships between the plant and the micro-organisms of the soil. In some instances in South Africa results are obtained which cannot be readily explained on the basis of mineral plant food substances added. Small quantities of organic manures have, in particular instances, given increases in yield out of all proportion to the mineral elements they contain. That the problem is here much more involved than was at first thought leaves no room for doubt.

Adaptation of crop types and varieties to different soils and climates, weed control by chemical means so as to reduce the amount and cost of cultivation, ploughless culture in all its implications, the efficiency of different grasses and legumes as soil builders, are problems which demand the maximum of co-operation for their effective solution, even though their investigation must unavoidably be spread over large areas.

The application of irrigation water to the soil brings in its train a host of perplexing problems. Until comparatively recently it was thought that in the drier areas all that was needed was more water. Salinization of irrigated soils is a matter not only of scientific but of economic significance. Changes in soil reaction, structure and life under irrigation are, as yet, little understood. Movements of soil moisture, effects of fertilizers, especially green-manures and other organic manures, are all matters in need of thorough-going inquiry.

PLANT GENETICS AND BREEDING

Few fields of research offer such opportunity for fruitful co-operative effort as genetics and plant breeding. The correct approach to problems in this field seems to be to regard a species or variety not as a final product which must be accepted or discarded in its entirety, but as a carrier of genes which might be put to good use in the development of new types.

A large part of genetic research could be centralized at a small number of stations, provided modern scientific equipment is provided. Closely associated with genetic problems cytological investigations could also be carried out. A cytological examination of indigenous species with economic possibilities or of likely value in plant breeding is urgently necessary. A case in point is that of many of our most promising pasture grasses. Some of them are partially or completely sterile, and it is impossible to attempt the development of fertile types until the causes of sterility are known.

In the field of plant breeding, environment is so important that in its final stages at least the work has necessarily to be decentralized, but certain highly technical investigations such as 'distant' hybridization and the artificial induction of polyploidy could be centred at a few institutions

equipped for the task. After difficult crosses are made or amphidiploids produced and carried through the first generation the material could be sent to outlying stations for further selection.

Although the more technical aspects of modern plant breeding lend themselves best to centralization, the pooling of resources in applied experimentation deserves consideration. In South Africa the ever-increasing demand for cereal grains necessitates an intensification of our breeding efforts with grain crops, especially maize. In this regard the use of 'hybrid' seed or of synthetic types developed from self-fertilized lines has become an important issue. We cannot hope to do maize breeding work on anything like the same scale as in the United States of America, but the testing, according to a co-ordinated plan, of as large a number of lines as possible from African and other sources for their combining ability and genetic superiority would be to the mutual benefit of all the States concerned. Here too it is essentially a matter of sorting out desirable genetic factors and employing them to the best advantage.

One general weakness of plant breeding in Southern Africa, apart from the small scale on which it is carried out, is that too little attention has been paid to indigenous species. It is not impossible that valuable material for the breeding of better adapted food and fodder crops could be found if a careful search were made for it. Such a search should extend over geographic areas to be in any way thorough and complete.

HORTICULTURE

The same general remarks apply to horticulture as to agronomy, though the possibilities of centralization might be somewhat more limited. Generally the view taken seems to be that fundamental research in this field should receive its stimulus from problems in applied science, and that only where such research is likely to be of wide interest and application would centralization be justified. Many of the difficulties which beset the horticultural industry are the legitimate responsibility of other branches of agricultural science, such as soil science, plant physiology, entomology and plant pathology. Low temperature research indirectly concerns horticulture to a greater extent than any other section of crop production and permits of some degree of centralization.

BOTANY

'The desirability of a Pan-African botanical policy is indisputable.' This was the theme of the presidential address to Section C of the South African Association for the Advancement of Science in 1941. The cogency of the arguments brought forward leaves no room for doubt, especially in so far as taxonomic botany is concerned because it is essential for a correct understanding of the flora of the African continent to study the whole as well as the part, in order that the component elements can be seen in their true perspective.

In the early days of botanical exploration in Africa all the plant material collected was shipped to Europe for description and lodging in numerous herbaria. 'African botany is, and is bound to remain, dependent to some extent for its progress on overseas herbaria. The degree of dependence

can, however, with no vital sacrifice on the part of the parent bodies, be decreased gradually. This may be accomplished by building up in one African institution a comprehensive library and a representative collection of authentically named specimens—in fact, a Pan-African botanical institution with an international staff.' *

The suggested central herbarium would naturally have to include a cryptogamic as well as a phanerogamic collection. African mycology is still in its infancy and a continent-wide study of the cryptogamic flora would not only be of scientific interest but also of economic value.

From an agricultural point of view, however, the study of systematic botany is perhaps of less immediate economic significance than other branches of botanical science, such as plant pathology and physiology. Facilities for full-scale investigations in these fields are expensive to provide and the time is overdue for the establishment of at least one African institution to which workers from all parts of the sub-continent could come for research on special problems. Air-conditioned greenhouses and laboratory equipment for the study under controlled conditions of plant viruses, bacterial and other diseases are a *sine qua non* for successful co-operative enterprise.

FORESTRY

Until recently forestry in the Union of South Africa, and perhaps more so in other parts of the continent, has been mainly exploitative. The natural forest resources are predominantly of the hardwood type and therefore of limited economic importance.

More than fifty years ago South Africa embarked on a policy of introducing and testing exotic species, since it was realized that indigenous species offered little if any scope for commercial afforestation. This policy has met with conspicuous success, so much so that hardwood supplies (Eucalypts) for mine props, etc., are now adequate, while softwoods are making a significant contribution to the country's economic and industrial development. Afforestation with conifers is proceeding apace, largely as a State enterprise.

Acre yields of timber are relatively high in comparison with those of Europe and America. This fact raises the question as to the most profitable method of land utilization. There is no doubt that in mountainous areas of high rainfall and leached-out acid soils, crop farming and perhaps also animal husbandry might have to make way for afforestation, not only from the point of view of profitable production, but also in the interests of soil amelioration and conservation, erosion control and regulation of stream flow.

Forestry research in the Union falls into three categories, viz. silvicultural, forest influences and forest products research. Investigations in the second category are of the greatest moment in connexion with the problem of watershed protection and call for expanded and co-ordinated effort by all African territories concerned, though complete centralization is neither desirable nor feasible.

One branch of forestry research which could be centralized is that dealing with forest products. In this case too, as in several others already

* *S.A. Jour. Sci.*, **38**, 56–68, 1942.

mentioned, costly facilities and equipment and specially trained staff are required and can be most economically provided through joint contribution.

ANIMAL HUSBANDRY

In consequence of the varied environmental conditions influencing and determining animal production, research in this field has of necessity to be regional in accordance with defined environmental areas. The basic problem is two-fold, viz. (*a*) the improvement of livestock, so as to obtain the maximum production within a given environment and (*b*) creating, within economic limits, conditions to suit the improved types and breeds of high-producing exogenous livestock.

The former is mainly a problem of extensive farming; the latter one of intensive production. After centuries of natural selection under exacting conditions of climate and prevalence of disease there must unquestionably have been created a large reservoir of valuable genetic material amongst indigenous livestock, yet no attempt has yet been made to capitalize this material in long-term scientific breeding experiments. As a preliminary to such experiments it is suggested that representative samples of various indigenous types be collected and brought together at some selected institution or institutions for study as to their reaction to climate and nutritional level, their disease resistance and fertility, and the mode of inheritance of certain desirable characteristics in crosses with high-producing European breeds. This would obviously be a long-term project and the indispensable continuity of effort could best be assured through a joint undertaking in command of adequate funds and facilities.

Improvement in the environment involves, amongst other factors, a higher level of nutrition based mainly on locally produced feedstuffs. Fundamental research in nutrition, and digestibility determinations on African feedstuffs is almost an open field which not only allows of but calls for concentration of forces and team work. In its applied phase these investigations would, however, have to be decentralized to link up with agronomic and pasture management problems, and to determine how animal production can best be integrated with other branches of agricultural production.

AGRICULTURAL ENGINEERING

In the past Africa has had no alternative but to accept implements designed for conditions in overseas countries, and although these have in the main been satisfactory there is room for improvement in design and performance to meet particular requirements of African agriculture.

A centre for the testing of agricultural machinery and the study of design with a view to making suggestions for improvement and laying down standards to manufacturers, whether on the continent or overseas, might be fully justified, for greater mechanization of African agriculture is bound to come.

The foregoing are but a few suggestions and by no means exhaustive or even indicative of all the possibilities for co-operative enterprise in agricultural research. How far any collaboration will be favcured, if at all,

by Governments and States is a matter for consideration by the appropriate authorities. It will in any case take years to elaborate a workable scheme and put it into operation, but there can be no doubt about the need for greater effort and higher endeavour if Africa is to continue to feed its own peoples and take its proper place in the world as a producer of agricultural products.

AFRICA AS A REGIONAL AREA FOR FUNDAMENTAL SCIENTIFIC RESEARCH

By Professor B. F. J. Schonland, C.B.E., F.R.S.

The future development of the African Continent * depends upon the intensive application of scientific research. The state of health of its inhabitants—white and black—is capable of enormous improvement by the further application of research to the study of tropical disease, public health and nutrition. It is evident already that recent discoveries make possible a considerable increase in its populaton, both white and black. The natural resources of the continent in animal and crop production, in the production of raw materials for industry and of minerals, are capable of very great expansion.

These developments will only take place if two quite different types of research organization are made available in Africa itself. The first is applied or 'service' research with short-term, *ad hoc*, objectives. This type of research organization is already developing throughout the continent. Scientific men in government employ are everywhere studying the application of the various sciences to the immediate needs of all African states and territories. Administrations are aware of the importance of such work and willing to pay for it. Scientific services of all kinds—agricultural, veterinary, geological, industrial, meteorological, medical and health—are growing everywhere. Though applied research organizations throughout Africa should be in close touch with each other and co-operate wherever possible, there is no possibility of any unification of such services nor is such unification desirable.

There is, however, no need to emphasize that applied research derives most of its value from research which is of a basic and long-term nature and without which applied research ceases after a time to be effective. Basic fundamental research, continually fed with the problems which the applied researcher meets and continually passing new techniques and ideas to be applied in practice, is essential for scientific progress.

It is inherent in the nature of fundamental research that it cannot be handled well by the same organization that deals with applied research. This is not primarily or even necessarily because of the restrictions and difficulties of close administrative control of such work. It is because the specialists qualified and available to do it are so few in number and the specialized equipment services and libraries they require are so elaborate and expensive.

For this reason alone the future development of Africa requires some measure of concentration of basic research. Even if sufficient 'background' specialists and if sufficient funds were available to permit of separate fundamental research organizations in various parts of the continent it

* In what follows, by Africa is meant the African Continent south of the Sahara.

would be wrong to use scientific resources in such a piecemeal manner. The political boundaries of the various African territories have no significance in the investigaton of their fundamental, as distinct from their day-to-day scientific problems. They are, in fact, a stumbling-block in the way of such investigations. Neither the weather, nor the geology nor the carriers of disease, nor the plant ecology of Africa can be properly studied without completely ignoring such artificial boundaries. To carry out fundamental entomological, meteorological, veterinary, geological, geophysical or botanical work in any one territory necessitates a complete co-ordination of observations and experiments in neighbouring territories. *For effective progress in such research work Africa should be regarded as one region and fundamental research developed by an organization on which all the African states and territories are represented.*

Some measure of pan-African collaboration in fundamental research already exists, but except in one special field—locust research—it is of an occasional and transient nature. Much closer co-ordination is needed and in many instances an actual merging of interests in one or more central research institutions is urgently necessary.

It is recognized that Africa is a very large area and that distance alone sets limits to the degree of concentration which can be contemplated. Moreover, Africa is an area of great diversity of climate and problems. Consideration of these matters may to some extent limit the number of cases in which concentration of fundamental studies is feasible or at any rate limit the area of the region over which it is feasible. But when all this has been taken into account, there remain a number of very important fields of inquiry which can and should be regionalized. Some examples of such fields are given below ; no doubt many others can be found.

General Subject	Branches which can with advantage be concentrated for one or more African 'regions'
Agriculture	soil conservation
Veterinary science	
Botany	plant physiology plant ecology plant genetics
Entomology	taxonomic entomology insect physiology and ecology long-range study of insecticides
Geology	correlation of strata the age of rocks geochemistry mineralogy
Geophysics	general studies magnetic and gravimetric surveying seismology the earth's heat

Meteorology	general African climatology long-range forecasting the circulation of the atmosphere thunderstorm studies
Forestry	Forestry and forest products research
Medicine	tropical diseases climatological medicine native nutrition
Engineering	building research soil mechanics
Physics	spectroscopy X-ray crystallography electron microscopy radar and radio
Chemistry	bacteriological chemistry

The precise manner in which research on the above subjects should be concentrated and the extent to which Africa could be regionalized for this purpose will require careful examination in each case. The form taken by particular centralized organizations will vary within wide limits, from a library and bureau of information or a centralized museum type of institution to a group of research laboratories staffed and equipped on an extensive scale. A few examples may be quoted :—

A Research institution on trypanosomes and tsetse flies serving most of the African territories and situated in Central Africa should be supported by them all.

Geophysics, Physics and Geochemistry could be centred in the Union of South Africa which is well equipped to deal with these subjects.

A series of regional geological and mineral information bureaux, sponsored by the interested governments should be established. One such bureau might have as its field the geologically rather similar territories of the Union of South Africa, South-West Africa, the Rhodesias, Nyasaland, Tanganyika, Kenya, Uganda, Zanzibar and Mauritius.

Fundamental research in the meteorology of Southern Africa might well be carried out as a joint enterprise between the Union and the Rhodesias, with its headquarters in a research institute in Southern Rhodesia. As a first step the Union has already formed a meteorological research committee which is attended by the Chief Meteorologist of Southern Rhodesia.

A Commonwealth Museum of African Entomology might be based upon the entomological collections in the Union.

Veterinary research should be concentrated at Onderstepoort and at Kabete in Kenya. Smaller laboratories could be maintained in other territories, but it is suggested that the big projects in veterinary research should be undertaken at these two centres which already possess well-equipped laboratories. Obviously, close contact will have to be maintained and an exchange of staff would be highly desirable.

The regionalization of fundamental research in Africa has so far been described as if it were a matter for African governments and territories alone. In fact, of course, most of the Empire territories in Africa come under the Colonial Office and can look to the Colonial Development Fund for support for research. It is axiomatic that any centralization of fundamental research of the kind suggested requires the support of the Colonial Office and its scientific advisers. It is also axiomatic that British research workers must share in every such centralized project in the Union of South Africa not as guests or visitors, but as partners in the enterprise, as would South African research workers attached to projects situated outside the boundaries of the Union.

The position of non-Commonwealth territories and their parent governments is a question for discussion. Their inclusion in certain of these regional projects would be of very great value to the projects themselves. Questions of sovereignty and national resources hardly arise when considering the centralization of *fundamental* research, though they are of some importance in connexion with applied research. In the writer's view non-Commonwealth Governments and territories should be invited at an early date to join in such regional research projects as are thought desirable, and to be associated co-operatively with others.

The development of the proposals outlined in this paper will take some time but the first steps should not be postponed. I would, therefore, suggest that the Conference recommend the setting up of a Commonwealth African Research Committee to examine proposals and put forward recommendations for the organization of fundamental research on African scientific problems *in Africa* and the manner in which such proposals should be initiated and financed.

REGIONAL RESEARCH IN AFRICA—VETERINARY SCIENCE

By Dr P. J. Du Toit
(Onderstepoort, South Africa)

From a veterinary point of view Africa, south of the Sahara, presents a very characteristic and uniform picture. Many of the diseases present here are confined to the African Continent ; and most diseases occurring in one territory are also to be found in the other territories of the Continent. Within this vast area there are no sharp boundaries delimiting diseases ; or where such boundaries exist they certainly do not coincide with the political boundaries which separate the different states.

Many examples could be quoted of diseases spreading across large parts of Africa, completely ignoring the boundaries, the state of civilization, or the particular form of government of the countries through which they pass. Perhaps the most classical example is rinderpest, which late in the last century crossed the Red Sea from Asia into Africa and then spread all the way down the Continent to within sight of Cape Town, leaving havoc in its wake. Another example is East Coast fever, which seems to have come from East Africa by sea to Beira at the beginning of this century and then to have spread from there to Southern Rhodesia and thence to the Union of South Africa and the other territories of southern Africa. Similarly, horsesickness (or African horsesickness, as it is frequently called) has spread to all parts of Africa where horses are kept and recently even penetrated to the delta of the Nile and beyond, to the Middle Eastern countries. Foot-and-mouth disease, too, has shown its disregard for boundaries by jumping, in spite of elaborate precautions, from one country to another since its reappearance in Southern Rhodesia in 1931. A more recent example is 'lumpy skin disease' of cattle which was first observed in Northern Rhodesia and has now spread to all the southern states.

These examples may suffice to show that when we consider the veterinary problems of Africa we must regard the Continent as one vast entity. In planning scientific research it would be folly to confine our attention to the requirements of one small area ; and it would be wasteful of our very limited resources in men and material to allow unnecessary duplication by undertaking the study of problems, which are identical, at several centres.

These remarks apply, of course, more particularly to long-range problems or problems of fundamental importance. Local problems or the application of the results of fundamental research to local conditions will remain the concern of each country.

It is now suggested that for long-range, fundamental research on veterinary problems of Africa two centres be selected, one in the south and the other in Central Africa. The two places which suggest themselves are Onderstepoort in South Africa and Kabete in Kenya. Both are con-

veniently situated near the capital city of the country ; both already possess well-equipped veterinary laboratories ; and both have an experienced, fairly large staff of scientific workers.

If this principle is agreed to, its application would not be difficult. The allocation of problems to either institute would be a matter of mutual agreement and would be determined by factors such as the availability of the necessary equipment and staff or the experience of the staff in that type of work. The results obtained would of course be available to everybody in the whole area.

Perhaps it would be profitable again to look at some of the major problems of Africa and to see how, in practice, the work could be allocated.

Fundamental work in bacteriology could be undertaken at Onderstepoort. Notable results have already been achieved both in the aerobic and anaerobic field. A recent example may be quoted to illustrate the value of such fundamental work and to show how it can benefit all countries in which the problem exists. Since the days of Pasteur attempts have been made to improve on the anthrax vaccine, first prepared by that great bacteriologist. The introduction, about twenty-five years ago, of a spore vaccine was certainly a great advance, but left much room for improvement. Further research at Onderstepoort by Sterne on variation in the anthrax bacillus led to the preparation of a vaccine from avirulent, uncapsulated strains. This vaccine has given extraordinarily satisfactory results in South Africa, where more than 30 million doses have been used since its first introduction. The vaccine or the strains from which it is prepared have been sent to many countries which thus have benefited from the research work at Onderstepoort.

The study of virus diseases has always occupied an important place in the research programme at Onderstepoort. Sir Arnold Theiler conducted his classical work on horsesickness at this centre, and the work has been continued without interruption and with considerable success since his retirement. The transmission of horsesickness to white mice by intracerebral injection, the elucidation of the plurality of the virus, and the attenuation of the virus by passage in white mice, were discoveries of fundamental importance which made possible the preparation of a vaccine which has proved to be of inestimable value to Africa. This work also led to other fundamental studies on viruses which have added much to our knowledge of this interesting and important group. It is obvious that Onderstepoort will have to continue to play an important part in research on viruses. Facilities are available for the determination of the size of virus particles, for the study of the electrical properties of viruses, for the application of colloid chemistry, etc. ; an electron microscope is now being installed. However, it is suggested that Onderstepoort, apart from a general study of the properties of viruses, should concentrate on those problems which are of particular interest to South Africa.

Kabete, on the other hand, might well concentrate on those problems which are of special interest to Central Africa. Rinderpest is an obvious choice, but there are other problems of no less importance. At a recent conference in Nairobi it was emphasized that foot-and-mouth disease had become a major problem in East Africa. Important work on this disease had already been started.

Kabete would also be the obvious centre where further research on tsetse flies and nagana should be undertaken. However, in this case the work would largely be decentralized at field stations in East Africa and elsewhere. But apart from the field work there will always be a certain amount of fundamental work which could well be centralized at Kabete.

General protozoological work could be undertaken both at Onderstepoort and at Kabete ; also work on the transmitters of protozoal diseases, especially ticks. Excellent work on ticks has already been done at both centres, and the recent addition at Onderstepoort of a specially equipped building for tick transmission work should greatly stimulate and help this work. Other entomological studies would naturally be undertaken concurrently.

In the field of helminthology it is also highly desirable to concentrate the more fundamental work at a few institutes. The life-histories of the parasites, the pathology of the diseases they produce, the influence of drugs on the parasites or other measures designed to break the life-cycle of the parasite or to save the life of the host—all these are problems which can only be studied satisfactorily in a well-equipped and sufficiently staffed institute.

Some phases of the study of poisonous plants can be tackled anywhere, but the isolation of their toxic principles and the determination of their structure are problems for a central institute.

Research on the pathology of diseases can only be done satisfactorily at a large institution. Also fundamental studies in physiology must be confined to a few institutes specially equipped for the purpose.

Only one more example will be added to this list. Nutrition has become a subject of major importance in veterinary science. The study of some of the fundamental aspects of animal nutrition requires specialized technique and fairly elaborate equipment. Onderstepoort has been conducting research into nutritional problems for many years and would be the natural centre at which such work would continue on a regional basis.

The examples quoted here are not intended to serve as the basis of a rigid research programme for the two institutes named. The intention is rather to show what type of research problem should be undertaken at the few selected central institutions. By concentrating the work at those few centres great advantages can be achieved, the greatest probably being the saving in specialized staff and specialized equipment. The greatest bar to progress in fundamental research in recent years has been the shortage of trained scientific staff. Even now that the war is over the shortage continues and it would be very unwise to dissipate our resources of human material by employing the available men at small institutions where their talents cannot be used to full advantage.

One great advantage of concentrating the scientific staff at a few larger institutions is the possibility of consultation between workers in allied fields. Not only does this apply to workers in the different branches of biology or medicine ; it applies equally to the chemist, the physicist, the statistician and various other specialists who have become indispensable partners of the biologist engaged in fundamental biological research. This concentration of specialists is of course only possible at the larger research institutes.

But apart from the personnel such institutes offer other advantages. Research without a good library is almost impossible. The information

services available to-day will only partly replace the actual reference library.

Another important item is equipment. Reference has already been made to some elaborate and costly items of equipment which can only be provided at the larger institutions. A few examples may be mentioned : high speed centrifuges, very low temperature refrigerators, electron microscope, micro-manipulator, fluorescence microscope, bomb-calorimeter, metabolism cages for large animals, and many more.

It is necessary to stress the point once again that this concentration at a few selected institutes applies to fundamental research only. The applied type of research will continue to be carried out, and must be encouraged and supported at the smaller research stations. In Africa we have excellent veterinary research stations at Salisbury in Southern Rhodesia, Mazabuka in Northern Rhodesia, Mpapwe in Tanganyika, Vom in Nigeria and at other centres. These will continue to fulfill a vital rôle in their respective countries ; but they would, under the scheme suggested, look to the two bigger institutions for the solution of their basic problems.

The central institutes should, in my opinion, continue to serve their own territories as heretofore by carrying out applied research, by undertaking diagnostic and advisory services, and even by manufacturing vaccines and performing other routine duties. My reason for suggesting this combination of functions is that, in practice, the countries concerned will probably not be able or willing to maintain parallel institutes, one undertaking only fundamental research and the other serving the immediate needs of the local population. But apart from this consideration I am of opinion that the contact between the fundamental research workers and the applied research or routine workers in the same institute is stimulating to both. In the case of the fundamental research worker this contact keeps him in touch with the realities of the problems he is investigating and will frequently suggest new problems to him.

But these additional duties should not be allowed to interfere with the primary function of the institute, namely, the carrying out of basic research. Effective measures should be insisted on to prevent basic research workers from being diverted to routine duties in times of staff shortage. *The continuity of and the adequate provision for fundamental research must be assured at all costs.*

It is probably unnecessary in this discussion to refer to the advisability or otherwise of combining a certain amount of teaching with research. If done in moderation such teaching may also have a great stimulating influence on the research worker.

In considering the problem of finance it is useful to recall the great work performed by the Empire Marketing Board. This body gave liberal support to research institutions in Great Britain, the Dominions and the Colonies. Apart from capital grants, research fellowships were awarded to outstanding scientists, who were thus enabled to investigate fundamental problems without fear of being detracted by extraneous duties. Excellent results were obtained and real progress made. The abolition of the Empire Marketing Board was a severe blow to scientific research in the Empire. The scheme now proposed, if put on a sound financial basis, may bear the same fruit as the E.M.B. scheme.

This matter should be examined by the Commonwealth African Research Committee suggested by Dr Schonland. The Committee will probably find it necessary to appoint subcommittees to examine special aspects of the problem. It is to be hoped that the present opportunity will not be lost to launch a scheme which may have very beneficial and far-reaching effects on the future development of the African Continent.

EVENING SUBJECTS

EVENING DISCUSSION ON COSMIC RAYS

Recommendations

The Conference recommends that the following investigations of cosmic radiation would be of great scientific value and are also likely to have important meteorological applications.

1. Further measurements of the variation with time of the cosmic ray intensity at selected stations at sea level and on mountains. Measurements in the southern hemisphere are of particular importance.
2. Further measurements of the variation of cosmic ray intensity with latitude and longitude by experiments in aircraft over a wide range of height.
3. The Conference recommends that steps be taken to encourage and to co-ordinate fundamental research in the field of radio waves, including ionospheric studies from stations on the magnetic equator.

The Conference recommends that the necessary organization to carry out the work should be set up in the first instance on an Empire basis, but that the question of extending the organization be raised at the next meeting of the International Union of Physics.

EVENING DISCUSSION ON FISH CULTURE AND MALARIA CONTROL

Recommendation

In view of the great possibilities of utilizing ponds for fish culture in various countries of the Commonwealth where malaria is prevalent, the Conference proposes that the attention of governments of countries so situated should be drawn to the urgent need of integrating fish culture practice with measures for malaria control.

AFTERNOON DISCUSSION ON GEOCHEMISTRY

Recommendation

Delegates attending this discussion endorse the recommendation contained in the Royal Society's Report on the needs of research in fundamental science after the war (p. 484, E, 27)—' that substantial provision should be made for quantitative spectrographic analysis of rocks, minerals and natural waters ' and further to recommend that adequate facilities in one or more institutions should be provided for like investigations (both fundamental and applied) on material which might be submitted from centres (including Colonial Geological Surveys and other geological organizations) within the British Empire.

EVENING DISCUSSION ON HORMONES

Recommendation

In view of the steady increase in the demand for insulin, the Conference urges that a strong recommendation be made to all the countries of the Commonwealth that every effort be made to collect, process and preserve all available pancreas. Purified insulin, which can be stored for long periods without loss of potency, will be needed on an increasing scale for the treatment of diabetes.

EVENING DISCUSSION ON THE VILLAGE POND IN THE RURAL ECONOMY OF INDIA

After a discussion on the above subject a further informal discussion on fishery and oceanographic problems in general was held. Thirty-six scientists concerned with fishery problems were present and the following recommendation was agreed.

Recommendation

'The oceanographic and fisheries scientists present as delegates to the Royal Society Empire Scientific Conference request its Steering Committee to arrange that if possible a meeting be called during the period of the Commonwealth Scientific Official Conference of these delegates, and other specialists available in this country, to discuss methods for co-operation and co-ordination of fisheries and oceanographical research within the Commonwealth, and similar matters of common interest.

'The above delegates also would appreciate any facilities which could be given for a tour to centres of fisheries research in the United Kingdom following the termination of the Official Conference.'

Addendum

Action on the above recommendation has already been taken.

SOIL MECHANICS METHODS IN NEW ZEALAND

By K. S. Birrell, M.Sc., A.R.I.C.
(Soil Research Bureau, Department of Scientific and Industrial Research, Wellington)

The soil testing work now being undertaken arose as a result of requests from civil engineers for advice on soil conditions, particularly with regard to aerodrome construction during the war. The laboratory is now fairly well equipped for making the standard types of tests for characterizing soils and finding out their mechanical properties. Owing to supply difficulties, much of the apparatus used has been designed and built in the Department's workshops, guided by the descriptions of apparatus published in the literature. Attention is now being paid to building up mechanized equipment for site exploration and sampling which will best suit our conditions.

Most of the work undertaken has been concerned with future projects rather than the examination of the behaviour of existing structures, but it seems imperative at the present stage to do more of the latter type of investigation in order to place our methods on a firmer basis.

Site exploration of soils for building foundations is now coming very much to the fore. When a variability survey of the site has been made, undisturbed samples are taken and tested in the laboratory, and from the results, anticipated settlements are calculated. With the larger and heavier structures now being planned, engineers are realising the value of a competently conducted site exploration and the essential nature of the soil information which can be obtained. Soil conditions in the vicinity of the larger cities are unfortunately usually complex. This factor adds to the difficulty of making a thorough survey, and in such instances the investigator is in a position to give only an estimate of the order of settlement to be expected. However, useful information to decide the suitability of sites and types of foundations should be obtainable in this way.

Instances given in the overseas literature of the prediction of building settlements seem invariably to be applied to the consolidation of one fairly homogeneous soil layer. If suitable instances can be found in New Zealand of observed building settlements where the soil is divisible into layers of different compressibility, a settlement analysis should reveal how far it is permissible to consider the anticipated settlements as additive.

A good deal of work has been done on the selection of materials for the construction of a large rolled-fill earth dam. A considerable quantity of undesirable material, consisting of heavy volcanic and sedimentary clays has had to be discarded, and the nature of the final mixes which it is economically feasible to use is such as to require fairly close control of moisture, density, and placed shear strength on the job. The moisture content range within which the outer section material will have the required

shear strength properties has been investigated in the laboratory, and particular attention has been paid to the effect of saturation on the final shear strength. For this purpose, samples of the material which have been compacted at different moisture contents, were allowed to saturate while loaded in such a way as to simulate conditions in the body of the dam. The uptake of water so found, agreed well with the anticipated increase as deduced from moisture density and zero air-voids curves. A well equipped soil mechanics laboratory has been established on the site of this dam, the staff having been trained in testing methods in the Department's laboratory.

The scope of the testing programme at the field laboratory will include control of borrow area materials with regard to grading and moisture content, determination of standards for compaction of fill material, checking of bank densities, and of placed shear strengths before and after saturation under the vertical loading appropriate to the depth of the material in the bank. Percentage air voids in placed materials are to be determined as a subsidiary check on the condition of the fill.

A study has been made of the permeability of pumice gravels in order to provide a basis for computing seepage losses through a block of porous country forming part of a storage area for hydro-electric purposes. The material showed no obvious signs of stratification, and determinations of the permeability when the porosity was adjusted by a packing procedure so as to be equal to that of the material in the natural state agreed fairly well with large scale tests *in situ* made by engineers.

Investigations have been made of soil conditions under bitumen aerodrome aprons where failure had occurred. Although only a small number of tests were made, confirmation was obtained in a general way of the criterion put forward by Glossop and Golder * that the shear strength of the soil should exceed $\frac{1}{\pi}$ times the maximum pressure which elasticity theory indicates would develop at a given depth due to the load of the aircraft wheels on the surface of the pavement. Where failure had occurred some layer was usually weaker in shear strength than the required value. Measurements taken at different seasons showed that where the water table in a clay soil is high in the winter, the soil does not dry out very appreciably under a sealed surface such as bitumen or concrete even in a dry season. Hence in the design of aerodrome pavements it may be economical to lower the ground water level as much as possible before construction.

It is proposed to co-operate with Public Works Department engineers in applying Glossop and Golder's method to the design of non-reinforced concrete runways on clay soils at a terminal aerodrome for overseas airliners. The results obtained by this method will be compared with data obtained by large scale loading tests and the California bearing ratio method. Attention will be paid in these tests to the soil conditions under the existing concrete runways.

Striking differences in the moisture holding capacities of groups of New Zealand soils of similar texture tested in connexion with this work have been noted. These differences are paralleled also by liquid and plastic

* Glossop, R. and Golder, H. Q. (1944), *J.Inst.C.E.* Road Paper, No. 25.

limit values and voids ratios. The fundamental reasons underlying these differences would appear to present an interesting subject for study; and it is proposed to attempt to correlate these findings with the mineral composition of the soil, particularly with regard to the clay minerals present.

The scope for soil mechanics development in New Zealand appears to be fairly promising, although complex soil strata may render impossible close estimates of soil behaviour. Government, local body, and private building programmes will be extensive within the next few years and many engineering projects will be on a larger scale than hitherto attempted. The application of soil mechanics will lead to better highways and more economically and safely designed structures and earthworks.

It is hoped that other engineering bodies will set up small laboratories in the more distant centres for routine soil testing, and that the function of the D.S.I.R. laboratory will be to concentrate on the developmental and research side of the subject.

TECHNOLOGICAL RESEARCH AT THE EXPERIMENTAL STATIONS OF THE FISHERIES RESEARCH BOARD OF CANADA AND ITS APPLICATION IN INDUSTRY

By Professor A. T. Cameron

(Chairman, Fisheries Research Board of Canada)

INTRODUCTION

The fishing industry is in but slight degree a chemical industry—only the development and production of certain by-products can properly be so termed. Yet the fishing industry utilizes research considerably, and not merely chemical research, but also research involving biology, physics, biochemistry, bacteriology and engineering. In Canada, while certain fishing companies have their own research laboratories, the bulk of the research for the industry as a whole is carried out by the Fisheries Research Board. To appreciate the mechanism of selection and direction of such research it is necessary to know something of the composition of the Board and its relations with the industry.

The Board is responsible to the Minister of Fisheries, and operates under its own Act of Parliament. Under the control of Treasury Board regulations, it controls its own expenditures. Its members therefore take a much greater interest in its affairs than if they merely constituted an advisory board. Its membership is fifteen, of whom nine are appointed on grounds of academic qualification, two represent the Department of Fisheries and four the industry (including the fishermen themselves). At the present time the 'academicians' consist of five zoologists, two biochemists, one bacteriologist and one physicist, these being professors from nine universities stretching from Dalhousie in the east to British Columbia in the west. Thus the Board's membership includes experts in almost every field of its activity.

The Board operates six stations; two marine biological, one fresh-water fisheries biological and three technological; the latter are at Halifax, serving the Maritime Provinces, at Vancouver, serving British Columbia principally and at Grand River, in the Gaspé peninsula, serving Quebec and the French-speaking north shore of New Brunswick. There is a fairly close association of the biological and technological stations, which has proved to be of advantage, since both are designed to serve the industry.

We term our technological stations 'fisheries experimental stations,' recognizing that the term is not too well chosen. The work of each of these stations is primarily chosen by its director. Of these, at present, one is a biochemist, one a chemist and one a bacteriologist. These directors are encouraged to maintain the closest contact with the industry, and actually do so, being greatly helped in this by the industrial members of the Board. They are therefore guided in their choice of work by actual knowledge of the problems of the industry, and are further guided by ad-

visory committees from the industry. The progress of researches actually being undertaken is reviewed, and plans for future work approved or revised at the Annual Meeting of the Board held at Ottawa each January, a meeting at which all the directors are present and such other of its scientists as it is feasible to bring half-way across a continent.

Subject to the approval of the Board itself, the directors can carry out researches suggested by industry, and also other researches initiated by themselves and their staffs and considered as being needed by industry.

The Board for many years has held the opinion that, since the money it spends is voted by Parliament for research to benefit the industry, the amount of pure research permissible to its staff must be limited to fit one of the following conditions : (*a*) whenever applied research is held up by insufficient fundamental knowledge, the requisite fundamental research should at once be undertaken ; (*b*) scientists in the employ of the Board may undertake such other fundamental research as does not interfere with the applied research for which they are primarily engaged.

At each of the two larger stations the scientists on the staff include biochemists, chemists, bacteriologists and engineers. The French-Canadian Station is but recently established and has a smaller staff. While later we hope that it will rank equally with the others at present its staff is chiefly occupied in adapting the results obtained at the Halifax Station to the needs of its particular clientele. The following review is therefore largely confined to results obtained at the Halifax and Vancouver Stations.

These two stations were established just over twenty years ago, at the insistence of the industry that the work of our biological stations was too academic, and without adequate relation to the problems of the industry. (Such a criticism may not have been entirely unjustified at that time, but is now neither justified nor made by industry.) The Pacific Station was located at Prince Rupert till 1942, when the exigencies of war forced its removal to Vancouver.

The functions of the technological stations are concerned with the development of proper methods for the handling and preservation of fish for food, and of marine products for purposes other than food (cf. Finn, A.R.,* 1936).

In dealing with the research activities of the stations no attempt has been made to assess priority of discovery. In some instances our scientists have been first in the field, in others parallel work was proceeding simultaneously in different countries, and in still others results obtained elsewhere were adapted to Canadian conditions. (Of course, in addition, our staffs also act as disseminators of pertinent scientific information, and answer a constant stream of inquiries from the industry.

RESEARCHES DESIGNED TO PROMOTE THE SALE OF FRESH FISH TO THE CONSUMER

Definition of terms

The consumer here referred to is the Canadian public, and by fresh fish is indicated fish that has been iced, or frozen, but not otherwise processed.

* See ' References ' on page 548.

It has gradually come to be realized that the development of its home market will play an important part in the stabilization of the Canadian Fishing Industry. There is ample room for it. In 1934 the annual *per capita* consumption of fish in Canada was about 21 lb., as compared with 40 lb. in Great Britain and 70 lb. in Norway. Furthermore, geographical location, rather than purchasing power, has been governing this consumption. In 1932 the average Maritime family consumed 50 per cent more fish than did a corresponding family in the inland provinces. Lack of quality is at once indicated as a cause of low consumption, and the importance of researches designed to improve quality becomes apparent (cf. Finn, A.R., 1936).

FROZEN FILLETS

The earliest major research of the Halifax Station was designed to demonstrate that frozen fish fillets could be prepared as a high grade product on the Maritime Coast, and marketed successfully in large inland cities even 2,000 miles away. This was accomplished. The research was commenced in 1926 under the direction of Dr A. G. Huntsman, then Director of that Station, and at the request of the Advisory Committee of the industry. Two years were needed for the necessary physical-chemical and engineering studies. Typical of these were the determination of the heat conductivity of frozen and unfrozen fish muscle, so that a prediction formula could be developed for calculation of the necessary time for freezing under set conditions. It was also shown that, for example, cod could be kept satisfactorily for a year at $-20°$ C. ($-4°$ F.) but that if held at $-5°$ C. ($+23°$ F.) there was marked spoilage. (Cf. Huntsman, A.R., 1929–1930.) An excellent product was placed on sale in Toronto, in January 1929. The retailers through whom this product was sold had considered that 600 lb. per week would be sufficient for trial purposes, but almost immediately, 1,000 lb. per week proved inadequate to meet the demand, though the price was definitely higher than that of unfrozen fillets of the same kind of fish (haddock, for the most part). Thus it was demonstrated that if meticulous care was exercised in using only absolutely fresh fish, in the processing and packaging, and in maintenance of the frozen condition until actual preparation for table, a first-class product could even be shipped as far as Winnipeg, as I can vouch for by my own experience there.

The experimental sales were so successful that the industry requested that production and distribution of the fillets be transferred to it ; this was done later in 1929. During the first fifteen months over 50 tons of these fillets were sold, chiefly in Toronto, but small quantities were also sold in Halifax, Montreal, Ottawa, Winnipeg and even as far west as Calgary, some 3,000 miles from the point of production But, although it was emphasized to the industry that maintenance of quality was of prime importance, the market was gradually spoiled by unloading on the public some materials of poor quality either insufficiently fresh when frozen, or held too long frozen. Moreover, at that period too few retail stores were adequately supplied with the means of maintaining the requisite low temperatures. By 1931 sales were at a low ebb, and shortly afterwards had virtually ceased. The method, successful when controlled by scientists,

could not yet be successfully entrusted to industry. The experiment was in advance of the time, for this type of process requires permanent rigid control from the death of the fish until it appears on the dining table, if the market is to be maintained. But the experiment had shown that whenever such control could be established, a first-class and most appetizing product could be guaranteed. (Cf. A. G. Huntsman, *Bull. XX, Biol. Bd. of Canada*, Ottawa, 1931.)

STUDIES IN QUICK FREEZING

Much of the later refrigeration work has been done at the Pacific Station, at first at Prince Rupert, and recently at Vancouver, Mr O. C. Young, now Chief Research Engineer there, being responsible for its direction, and for most of the actual research. It has been determined that best results are obtained by quick freezing to at least −20° F. A certain critical rate of freezing is necessary to produce a frozen flesh that will retain its juices and texture when thawed for consumption. For best results the temperature of the flesh must fall from 32° to 23° F. in not more than 35 minutes. During holding at low temperatures shrinkage due to dehydration must be avoided, and this is best done by maintaining the low temperature by a relatively large area of cooling coil kept near the temperature of the cold chamber, and causing a less degree of distillation than would a smaller coil kept at a much lower temperature (cf. A.R., 1932, 1933, 1934).

Valuable data concerning the relative efficiency of different refrigerating conditions, and of other treatments, have been obtained by setting up tasting panels at Prince Rupert (and later at Vancouver and at Halifax), both among the staff, and among families in these cities. From experiments with these panels it was established that very fresh halibut is usually considered tasteless, while when it has been kept iced for over eleven days, it is stale ; the preferred flavour, to most people, is that of such fish kept from five to seven days (A.R., 1937, 1938). Also, when such iced halibut is held six days or longer, before quick freezing, the results are less satisfactory. For adequate preservation over long periods, the maintenance temperature should not exceed +5° F., and should preferably be kept below 0° F. (A.R., 1937).

With equal storage temperatures, the taste panels preferred quickly frozen to slowly frozen fish (A.R., 1938). While it is generally agreed that such quickly frozen fish, kept properly refrigerated, yields the most palatable product when thawed immediately before, or during the actual preparation for the table, yet exigencies of distribution sometimes require earlier thawing. It has been determined that when fish have to be held unfrozen for periods not exceeding four days, diminution of flavour and quality due to loss of juices as 'drip' is less with slow than with rapid thawing (A.R., 1941).

In large continental areas such as Canada the problem of bringing fish that are landed in really fresh condition to consumers at distant points still in that fresh condition can undoubtedly best be solved by proper refrigeration procedures ; quick freezing, storage and transportation in frozen condition, and sale to the consumer still frozen. Thawing and re-freezing at any point in this chain spoils the product. Facilities throughout

Canada for holding frozen foods in retail stores have now greatly improved, and a considerable increase in this method of distributing fish is to be expected. Nevertheless, it must be stressed that while unfrozen fish is almost as perishable as milk, frozen fish is still semi-perishable and, in the light of present knowledge, refrigeration should be used as a means of preserving fish during the minimum time required for distribution, rather than as a means of carrying fish over from periods of plenty to periods of scarcity. After prolonged storage at low temperatures frozen fish loses its flavour and becomes somewhat tough and unappetizing.

Railway refrigeration

Distribution in Canada not only calls for proper freezing and proper holding in cold storage, but also proper transportation in frozen condition. Considerable attention has been given by Mr Young to the improvement of the design of railway refrigeration cars. The customary type of such cars in Canada up to a dozen years ago was the so-called ' end-bunkered ' car, with compartments at each end containing ice-salt mixtures for the cooling of the central chamber. Experiments commenced in 1932 showed that an ice-salt bunker placed at the top of the car gave much better results. Co-operation was obtained with both the Canadian National and the Canadian Pacific Railways, and the former assisted greatly in the early experiments at Prince Rupert. Both constructed experimental cars of this new design. In 1936 a trial run was made during the heat of July over the Canadian Pacific Railway from Vancouver to Winnipeg (1,500 miles) with a fish shipment, and from Winnipeg to Montreal (1,400 miles) with meat. During the latter half of the trip a direct comparison was made with an end-bunkered car. The results were most satisfactory. The temperature throughout the interior of the new car never exceeded 23° F. The advantages were summed up as (*a*) more rapid initial cooling of the car and load, (*b*) more uniform temperature distribution, (*c*) lower mean temperatures for a given concentration and amount of the ice-salt refrigerant, (*d*) more economical operation, and (*e*) approximately 25 per cent greater load capacity due to removal of the end-bunkers (A.R., 1936). In July 1937 a second trial-trip was made over the Canadian Pacific Railway from Vancouver to Montreal, and it was shown that sub-zero temperatures (Fahrenheit) could be maintained, using ice-salt and ' dry-ice,' at a not prohibitive cost (Pacific ' Progress Report,' No. 34). The Canadian National Railway ran a trial trip, along with an end-bunker control car, from Prince Rupert to Montreal, and part of the consignment was then shipped to England, Mr Young accompanying it to London. He found that the only two weak links in the long chain were transhipment at Montreal, and unloading and transhipment to cold storage in the Thames (A.R., 1937). The advantage of the overhead-bunkered car was fully established by these experiments, and all new construction by both railways is now of this type. Additional proof of its greater efficacy is shown by the difficulty both railways are said to experience in reclaiming these cars from the United States whenever they are consigned there with shipments.

Recently Mr Young has commenced studies designed to improve such transportation facilities further, since it is the definite opinion both of

himself and the fishing industry that perfect results cannot be attained with ice-salt mixtures. In experiments at Vancouver with a stationary railway car he achieved some success by replacing the ice-salt mixture by a number of closed containers filled with a 20 per cent sodium hydroxide solution, which gives a eutectic ice at $-21°$ F. He is also testing out the possibility of associating with such containers a mechanical refrigeration unit, driven from the axle of the moving car (A.R., 1944, 1945).

Such a radical change from present operating methods obviously needs most careful consideration before it can be seriously attempted by the railways. At our request the Canadian National Research Council called a meeting last January of our and their experts in this field, and of representatives of both railways and of all those groups, including the fishing industry, which ship frozen foods. We hope that, as a result of the very interesting discussions there, steady and planned progress can be made to produce still greater improvement in refrigeration transportation.

Maintenance of freshness

In 1934 the staff of the Halifax Station started a systematic research designed to improve the condition of fish (particularly cod and haddock) in the fishing vessels, in the processing factories, in transportation and in the hands of wholesalers and retailers, to the end that fresher fish could be placed in the hands of the consumer (A.R., 1934).

It was necessary to have a simple method of estimating the degree of staleness of fish. Such a method had been devised in 1932 by Drs Beatty and Collins (A.R., 1932); it consisted in the estimation of the volatile base trimethylamine, which is liberated in fish muscle in increasing amounts as the bacterial population increases. Spoilage odours arise when it is present to the extent of 5 mg. per cent trimethylamine-nitrogen (A.R., 1936; *J. Biol. Board of Canada*, 3, 77 (1936)).

The compound is produced from trimethylamine oxide, which is present in amounts varying, according to species, from 0·15 to 1·5 per cent in the flesh of all the ordinary sea fish of the Canadian Atlantic waters. Trimethylamine is not a normal metabolite of the fish and is not liberated in autolysis of its flesh; the oxide acts as an oxygen-donator for certain bacteria active in the spoilage process, thus permitting anaerobic spoilage (A.R., 1937).

Using the trimethylamine test it was shown that when cod and haddock fillets were kept at 0° C. under ideal conditions at eight days the content of the base was negligible, after eleven days 4 mg. (trimethylamine-nitrogen) were present, and then there was a sharp rise to 18 mg. at thirteen days (A.R., 1936). Further studies of spoilage showed that in the early stage sugar disappeared while lactic acid increased; as trimethylamine appeared, the lactic acid was replaced by acetic acid. Proteins and amino-acids were not affected until the trimethylamine concentration indicated marked spoilage (A.R., 1938, 1940). Incidentally, it was also shown, in confirmation of results at the Torry Research Station, that dimethylamine is produced in the early stage of spoilage.

In gutted cod or haddock the lining of the body cavity spoils first, the intestines being the most serious source of bacterial infection (A.R., 1935). Surfaces are heavily contaminated with bacteria. The interior of fillets is

sterile, and if they are well washed they remain fresh. The major changes rendering fish unfit for consumption occur at or near a surface. It was found that the pH of the surface is a satisfactory index of the state of preservation. Initially it becomes slightly more acid, but, as bacterial action increases, it rapidly becomes alkaline, so that an alkaline surface on commercial fish or fillets indicates bacterial spoilage, which is detectable earlier in this way than by odour.

In the middle thirties, using the trimethylamine test as criterion of staleness, a systematic study was made of the quality of fish as sold in retail stores in Toronto and Montreal, and subsequently in Halifax itself. The results were so poor that it did not seem wise to publish them then, though they were communicated to the industry.

In 1942 a survey of plants used for the preparation of fillets showed that much surface pollution occurred during the preparation of fillets. This fact was brought to the attention of the fresh fish producers, and plans were made for a major clean-up of such plants. A new fillet-cutting table was designed, with water conveyors for movement of round fish to the cutters and for removal of the completed fillets and the offal from the cutting table ; one such table was installed by a commercial company in 1942 (A.R., 1942) with such obviously good results that two more plants adopted this type of table in the following year (A.R., 1943).

The general attack on the whole problem of improving practices in the fresh fish trade was greatly assisted in 1943 and subsequent years through the supervision exercised by the Department of Fisheries in conjunction with the staff of the Halifax Station, in ensuring the high quality of the several million pounds of east coast cod and pollock fillets and flounders shipped to Great Britain by Canadian processors in terms of contracts with the British Ministry of Food. An inspection procedure was developed, inspectors were trained and their judgment in the field was checked by laboratory analyses for decomposition products. The work seems to have been definitely successful. Defects in the current methods of handling fish were brought to light and corrected. I understand that the officials of the British Ministry of Food were well satisfied with the quality of the fish supplied.

This was the first experience of the fresh fish trade of the Maritimes with governmental inspection and the members of the trade were so favourably impressed that they requested that this type of inspection be extended to cover their whole production (A.R., 1943, 1944).

Recent studies have included examination of the purity of the water supplies (both of fresh and sea water) used in the various plants (A.R., 1944) and the state of preservation of fish as landed from trawlers and schooners. Fish landed from trawlers throughout the year, and from schooners in winter, were found to be in good condition, but during the summer fish from the latter tended to be somewhat less satisfactory. Although the amount of fish landed in poor condition was small, yet it was felt that it could be made much smaller (A.R., 1944), and therefore some studies were made on the handling of fish at sea. These suggest that there is unnecessary forking of fish on the schooners, and that forking through the body—too frequent—tends to spread bacterial infection. Storage in ice aboard the schooners is frequently faulty. Excessive leeching

from melting ice is not improbably deleterious through removing compounds from the fish flesh responsible for the palatable flavour. Insulation on many of the vessels is capable of improvement (A.R., 1945).

Corresponding studies with similar design have been concurrently carried out by members of the staff of the Pacific Station. An investigation as to the cause of discoloration of halibut (lessening its sales value) incriminated a specific bacterium infesting the holds of fishing vessels (A.R., 1929–1930). This led to the testing of the relative efficacy of various germicides. Formalin was considered to be the best available. Disinfection of vessel holds with formalin spray was started at Prince Rupert, rapidly increased there, spread to Vancouver, and subsequently to the East Coast also (A.R., 1934, 1935). By 1936, 80 per cent of the total amount of halibut landed at Prince Rupert from Canadian vessels was from vessels so treated. (This formalin method of disinfection was subsequently adapted for use in salmon canneries (A.R., 1936). Recently a spray consisting of 1 per cent formaldehyde containing 0·01 per cent sodium nitrite has been advised, the latter lessening corrosion of any metal parts (A.R., 1944). In addition, antiseptic ices incorporating a little benzoic acid (0·1 per cent) or some similar agent were tested and recommended (A.R., 1935), while antiseptic ice glazes have also proved useful.

Studies of spoilage of halibut gave similar results to those obtained for cod and haddock at the Eastern Station. Such studies indicated that with the best commercial handling halibut remains ‘ fresh ’ until the tenth day after it was caught, ‘ doubtful ’ until the fifteenth day and then rapidly stales.

It was found that the trimethylamine method of measuring freshness does not give accurate results with most of the Pacific commercial fishes. Instead, Dr H. L. A. Tarr, bacteriologist at the Station, uses a direct bacterial count (A.R. 1939, 1941, 1942, 1944).

Preservatives

It is natural that attempts should be made to prolong the freshness of fish by use of chemical preservatives, although such treatment may conflict with Food and Drug regulations, according to which an untreated stale fish may still be legally fresh, while a treated fresh fish can no longer legally be so termed. The legal difficulties have still to be ironed out, but in the meantime some useful knowledge of suitable preservatives has been acquired and published.

The definitely dangerous potentialities of boracic acid as a preservative are now well recognized, and any substitute harmless to man which will banish its use should be welcomed. Benzoate is less harmful, since the body possesses an excellent mechanism for its detoxication, but the very existence of this mechanism suggests that it should not be considered ideal. Dr Tarr has shown that sodium nitrite is a better preservative than benzoic acid for the commercial Pacific fishes. (Thus fillets dipped for five minutes in 15 to 20 per cent brine solution containing 0·4 to 0·5 per cent sodium nitrite remain in good condition longer than with brine alone, and much longer than untreated fillets. The nitrite taken up by the flesh does not exceed the legal limits permitted for processed meat, and the salt acts as a condiment (A.R., 1939). Nitrite ice is better than benzoic acid ice

(A.R., 1939) and has been recommended for icing the bellies of gutted fish on the fishing vessels (Halifax, A.R., 1944).

Nitrite hinders bacterial growth on fish flesh, slight acidity of fresh flesh favouring its action (A.R., 1939, 1940), but is not effective in flesh that is neutral or slightly alkaline (as that of shell-fish) for which hydroxylamine is a fairly efficient substitute (A.R., 1945). The restraining influence of nitrite is selective for the bacterial population; it is a very effective preservative in delaying onset of spoilage odours (Halifax, A.R., 1945). Tests on laboratory animals have shown complete absence of toxicity of nitrite fed over long periods in amounts corresponding to the maximal quantities that can be obtained from nitrite-treated fish flesh (A.R., 1941).

Fat species of fish even under the best conditions of cold storage tend to develop some degree of rancidity. Of various antioxidants tested for ability to prevent this, the best so far found is ethyl gallate (a close chemical relative of tannin of tea) which is effective in concentrations between 0·01 and 0·05 per cent (A.R., 1944, 1945). Ascorbic acid is also excellent for this purpose (A.R., 1945).

RESEARCHES DESIGNED TO IMPROVE TRADE PRACTICES OF PROCESSING FISH

Smoking

The smoking of fish in the Maritimes is, in traditional trade practice' a three-stage operation, first, brining to a salt concentration of 2½ per cent, then drying to the stage of a sticky surface and finally the actual smoking. The staff of the Halifax Station has improved all three stages and combined the last two; their improvements are rapidly being adopted by the industry. At certain seasons of the year, owing to high humidity and temperature, smoking by the old methods was virtually impossible. In the new procedures it is independent of external weather conditions.

Initially, fundamental studies were carried out to determine the limiting values of temperature and humidity for successful drying. Then experiments with air-conditioning apparatus showed that fillets could be smoked in four to six hours, instead of the customary twenty-four hours. An experimental tunnel-drier was built and tested. (Cf. A.R., 1931, 1933, 1934, 1935.)

In 1937 Dr D. L. Cooper designed and built a small smoke-house, semi-automatically controlled, with inside dimensions 8 ft × 8 ft × 6 ft; the smoke was generated in an external burner. The capacity was 700 lb. of fillets. Heated air could first be circulated for preliminary drying, while the smoke could be recirculated. Five hours were required for drying and smoking cod or haddock fillets, so that the twenty-four-hour capacity was over 1½ tons. It operated successfully with external weather conditions varying from 38° F. and 80 per cent relative humidity to 80° F. and 100 per cent relative humidity. It cost 350 dollars to install, which was considerably less than half the cost of the old-type dryers. The demonstration that this type of smoke-house provided economy of space, ease of control and flexibility of type, along with very low first cost and low operating cost was so obvious that in that year four firms installed houses of this type (A.R., 1937).

In 1938 scientists of the Gaspé Station assisted in the installation of seven commercial smoke-houses of this type, situated all the way from the Island of Orleans to the Magdalene Islands, while in 1940 they helped with installation of six slightly larger houses, 12 ft×8 ft×8 ft. They also demonstrated that in such smoke-houses herring, eel and sturgeon could be successfully processed (A.R., 1939, 1940).

Within the last two or three years Dr Linton and Mr Wood of the Halifax Station have designed a still further improved model, a cross-draft smoke-tunnel in which drying and smoking are carried on simultaneously ; this tunnel has been found especially useful for smoked canned herring and 'kippered snacks.' (Atlantic 'Progress Report,' No. 34 ; A.R., 1945.) Because of the relatively greater demand for fresh fish, local interest in these dryers only became marked in the Maritimes late in 1944, but a number have now been constructed. Previously, I am informed, several were built in Newfoundland, and at least one in Great Britain (A.R., 1944).

The marked acceleration of drying and smoking in these new types made brining the bottle-neck of the whole operation. An experimental continuous briner has now been designed, with a special non-chokeable nozzle using a spray of concentrated salt solution, by which enough salt is taken up by the fish in less than four minutes ; this is being tried out on the commercial scale (A.R., 1945).

Throughout this research numerous attempts have been made to improve and standardize the methods for actual production of the smoke ; while improvements have been made, undoubtedly still further improvement is possible and will be accomplished.

The Pacific Station staff showed that with such smoke-houses many of the Pacific fishes could be successfully smoked (A.R., 1938), paying particular attention to the cheaper species, of otherwise low marketable value. Mr Young has recently devised a somewhat different type of all-purpose tunnel (A.R., 1945).

Salting

Various initial fundamental studies were carried out at the Halifax Station. These were spread over a number of years, and included an investigation of the relation between water, salt and the protein of fish flesh, studies of the drying of muscle and of the effect of different grades of salt on the bacterial population (A.R., 1929–1930, 1935, 1936).

Successful salting involves the successful drying of fish and its proper storage, and this depends in part on the reduction of its water content to a certain level, and the maintaining of it at that level. Therefore it was essential to determine how much water the fish flesh would gain or lose under different degrees of relative humidity and at what rate this change proceeded. Such data were ascertained for 'hard-salted' fish, which were found to behave at high humidities like a saturated solution of sodium chloride (A.R., 1936).

The weather in the Maritimes is such that salted fish are air-dried with considerable difficulty. In some regions this cannot be done at all, in others only certain types can be produced, and in the past considerable losses have been incurred over the whole coast.

The object of the research has been to render the process entirely independent of weather conditions. Hence : (*a*) Conditions were determined under which heavily salted hard-dried fish should be stored, so that they would neither give up water to the air nor take water from it. (*b*) The temperature, velocity and humidity of air most desirable for the drying of fish from the standpoint of economy of operation and quality of the finished product were worked out, using small portions of salted fish in the laboratory. (*c*) Experimental tunnels capable of drying whole fish were constructed, and the results checked with them. (*d*) The results were then used as a guide in the construction of a large dryer in 1939, in a commercial plant, for and at the request of the owners of the plant. (*e*) In order to check the data on a semi-commercial scale, and to check information obtained from the industry, a pilot plant was erected at the Station. (*f*) The first large scale dryer gave such good results that two more large commercial dryers have been constructed by the industry, the staff of the Station furnishing the requisite data (A.R., 1940, 1941, 1942).

The design of such dryers needed accurate data as to temperatures and humidities over the whole coast, and these were obtained.

Sun-drying is slightly cheaper than the most economical artificial dryer, but the improvement in quality of the product, and absence of loss more than compensate for the difference in cost of processing.

The almost complete change from outdoor drying to tunnel drying has been an outstanding example of co-operation between the members of the industry concerned, and the research workers. Further developments have been the design of a smaller tunnel suitable for the small 'shore-operator,' and studies designed to improve the production of 'light-salted' fish. A number of such small commercial dryers have now been constructed for production of hard-dried cod, and pollock, shredded cod and boneless cod. Dr S. A. Beatty, Director of the Station, reported in 1944 that the amount of sun-dried fish produced in the area served by it will soon be negligible (A.R., 1944).

The salt fish trade had to fight a special type of spoilage. Salting and drying halt the actions of ordinary spoilage bacteria, but three types of organisms capable of living and multiplying in presence of marked concentrations of sodium chloride cause an appreciable annual loss. These are slime-forming bacteria, which may affect the undried fish during warm, humid weather, 'red' bacteria and brown moulds termed 'dun.' The last two cause the greatest losses (A.R., 1940).

'Red' is encountered usually in heavily salted fish during warm, humid weather. It causes particularly heavy spoilage losses in 'boneless cod,' and in the dry fish trade after the fish reach the tropics where most of such dry fish are sold. Investigation indicated that the best way of controlling this type of spoilage was the rigid cleaning and sterilization of fish establishments infected with the organism. Formaldehyde vapour, sulphur dioxide and chlorine were demonstrated to the industry as effective agents for this purpose, and one or the other was adopted for commercial use (A.R., 1938, 1943). It was further found that 'solar-salt' (from evaporated sea water) is frequently contaminated with the organism, and that such contaminated salt must be rigidly avoided. By this combination of dis-

infection of premises and use of proper salt it has been shown that losses from 'red' can be made negligible (A.R., 1940).

Spoilage losses from 'dun' are chiefly with 'slack-salted' fish. Study showed that there are two types of mould involved, of which one grows only in presence of salt, while the other can grow in its presence or absence, and has been isolated from many sources. These moulds grow best at the same relative humidity (70 per cent) which is best for stored salted fish. Ease of spread of the spores renders it unlikely that contamination can be avoided. The effect of various chemicals in arresting mould growth has been tested; sodium propionate is effective but costly, and no cheap effective material has been found (A.R., 1940). However, losses from 'dun' now appear to have become negligible in plants equipped with tunnel dryers and air-conditioned storage chambers (A.R., 1945).

It may be mentioned in passing that the duties of the staffs of the technological stations not only involve designs of new plants but also advice in installation, whenever the industry adopts such designs. As a result, in recent years, the time of the engineering staff of the Halifax Station has become almost completely occupied in giving such assistance, and in adapting the general principles of the new methods to the particular needs and possibilities of individual premises. Such work includes filleting plant design, cannery design, refrigeration installation and installation of tunnel dryers and smokers. At present its extent is limited solely by the availability of the necessary personnel.

Canning

Early work on canning at the Halifax Station was largely concerned with the experimental canning of mackerel, tuna, 'marinated herring,' scallops, etc., and the improvement and standardization of lobster canning (A.R., 1929–1930, 1931, 1932, 1933, 1934, 1937). As early as 1930 inspection and grading of lobster canneries was started, and by 1932 it had become routine (A.R., 1932).

Previous to the war four-fifths of the annual canned lobster pack was marketed in the British Isles and Europe. But lobster is a luxury food, and the war closed this market. Nevertheless since this valuable fishery supports many coastal communities a market on the North American continent had to be found instead, and the product adapted to the desires of this new market. In 1940 Dr E. Hess, Chief Bacteriologist at the Halifax Station, was loaned to the Department of Fisheries for inspection of the canned pack, which proved so satisfactory that it has gradually been extended. It has gradually eliminated various faulty practices, such as over-cooking, over-processing and packing of weak or soft-shelled lobsters (giving a soft, undesirable product) (A.R., 1942).

Canned lobsters sometimes contain crystals of ammonium magnesium phosphate, which sufficiently resemble glass to excite the suspicion of the consumer. It has been shown that if sea water (source of the magnesium) is eliminated during processing, the crystals do not form (A.R., 1942).

Canning experiments at the other stations were started later, and have been largely confined to the development of new products such as cod livers (A.R., 1938) and eels (A.R., 1939) at the Gaspé Station, and halibut cheeks in jelly, and smoked black cod at the Pacific Station (A.R., 1940).

RESEARCHES DESIGNED TO DEVELOP VARIOUS FISH PRODUCTS

Specialty products

Very recently the Vancouver Station has established a kitchen to demonstrate to the industry that a variety of materials, otherwise of little value, can be successfully prepared for marketing as fish pastes, fish loaves, fish sausages, etc. (A.R., 1945).

Cod-liver oil

The staff of the Gaspé Station designed a small apparatus for extraction of the oil, suitable for the use of scattered operators along the coast of the peninsula (A.R., 1938, 1939) and later modified it to give a semi-continuous extraction in a plant of 45 gallons capacity (A.R., 1940).

Prior to the war Canada imported most of the cod-liver oil she needed. The sources of this imported oil being cut off it became necessary to develop the Canadian sources and to improve procedures. The Halifax Station devised methods for utilizing cod livers in isolated communities to give a good product, and for the better preservation of the livers (A.R., 1940). A method was devised also for deodorizing oil of high vitamin potency but of objectionable odour and flavour (A.R., 1941).

In joint work, scientists of the Gaspé and Halifax Stations developed a simple alkali-refining process for seal oil and for cod-liver oil, which removes free fatty acids, eliminates most of the colour pigments and does not affect the content of vitamin A (A.R., 1942).

Vitamins and oils from Pacific fishes

The scientists of the Pacific Station, while it was situated at Prince Rupert, carried out a masterly series of investigations on the vitamin contents of various marine fish oils, and on the industrial utilization of such oils. The work was guided by Dr D. B. Finn, while he was Director of that Station, and was largely performed by Dr H. N. Brocklesby and his assistants.

Vitamin assays carried out during 1927–1932 assisted in establishing a demand for halibut livers, formerly wasted, and thereby materially increased the earnings of the fishermen in the port of Prince Rupert and elsewhere. It was shown that the liver oils of ling cod and of salmon had high vitamin potency, and that pilchard oil was a valuable supplement in the diet of poultry and of cattle, providing vitamin D. It was further shown that the Pacific dog fish liver oil was rich in vitamin A, and that a blending of pilchard oil and dog fish liver oil (' Thallatol ') was as efficient for human consumption as a good cod-liver oil or even better (A.R., 1932, 1934). By 1937 the industrial use of dog fish liver oil was considerable (A.R., 1937) and in recent years it has even been great enough to suggest the possibility that the species of fish is becoming depleted.

Variations of the vitamin contents of such oils with season and geographically were determined. The latter were negligible (A.R., 1936). Viscera oils were tested for vitamins and some were found to be valuable (A.R., 1937). Improved methods were elaborated for separating the oil from liver tissues and were adopted by industry (A.R., 1935).

Numerous hydrogenation and other studies were made, especially with pilchard oil, and processes were worked out for preparing from this oil frying oils and shortening fats, paints, varnishes, waterproof fabrics, etc. (A.R., 1932, 1933, 1934, 1935).

Concerning the vitamin results alone, Dr N. M. Carter, now Director of the Station, wrote in 1943 : ' Largely as a result of the Station's early investigations on the vitamins A and D content of British Columbia fish oils commencing in 1927, vitamin oils from British Columbia fish livers and viscera alone to the value of over 2,500,000 dollars have been produced in the past decade, with seven plants operating in 1942 in this relatively new industry in the Province ' (A.R., 1943).

Recent vitamin work has been chiefly directed towards better extraction and concentration of the vitamins (cf. A.R., 1941).

Similar use has been made by industry of the research results on the industrial utilization of pilchard and other oils.

In 1941 the Board published its Bulletin No. 59 on ' The Chemistry and Technology of Marine Animal Oils with Particular Reference to those of Canada.' This was edited and largely written by Dr Brocklesby. He had already established himself as one of the leading authorities on oils and fats in North America, and this volume enhanced his reputation still further. Industry had already made several efforts to take him from us, and now finally succeeded, illustrating one of the difficulties that governmental scientific bodies experience, the retention of first-class men when industry decides to buy them.

Fish meal and glues

The Halifax Station has carried out studies from time to time designed to improve the quality of fish meal (A.R., 1932, 1933). Both the Pacific and Halifax Stations did some experimental work on the production of glues from the waste liquors of fish meal plants (A.R., 1929–1930, 1930, 1931), and the latter successfully worked out a process whereby non-gelatinous proteins and salts were removed from such effluents ; by 1939 one or two commercial glue plants were already in successful operation in Nova Scotia (A.R., 1938, 1939).

Leather bates

These enzyme preparations, used for tanning, have been imported into Canada. At the Halifax Station it has been shown that enzyme preparations can be obtained from the pyloric caeca of commercial fishes, equal in potency to any of the ordinary commercial leather bates, and a valuable use has thus been suggested for what was previously waste offal (A.R., 1936, 1937, 1939, 1940).

OTHER WORK

Nutritive value of fish

Early work at the Pacific Station was limited to the determination of the ' proximate principles ' of the flesh of different species of fish and was not of great value. Recently Dr J. M. R. Beveridge has made at that Station some more fundamental studies of the comparative biological value

of fish foods as judged by growth of rats, etc. He seems to have shown that halibut flesh, as a source of proteins, is superior to beef flesh, mixed milk proteins and egg albumin, while the flesh of ling cod, lemon sole and white spring salmon is of the same order of value as halibut. While such superiority will undoubtedly require further evidence before it is generally admitted, his results certainly indicate that fish flesh is at least equal to mammalian flesh in protein value. On the other hand, he has shown that it is relatively poor in one or more of the B vitamins (A.R., 1945).

AGAR

The war with Japan cut off the chief supply of agar. In co-operative work with the British Columbia Scientific and Industrial Research Council, the staff of the Vancouver Station has shown that certain local red seaweeds can be used as source of an excellent agar (A.R., 1944, 1945).

CONCLUSION

In this outline of the main lines of work that have been carried on at the technological stations of the Fisheries Research Board of Canada, I have endeavoured to indicate how, by constant consultation and close co-operation with the industry, the staffs of the stations have been enabled to improve very many of the practices of the industry, and also that some of their researches have led to new industrial developments.

Much of the progress has been due to the initiative and hard work of the directors and their staffs. But without the wholehearted co-operation of the industry, its readiness to supply production data and other pertinent information, and the readiness of many of its member firms to permit large-scale trial of promising developments in their establishments, with adequate publicity of the results to the whole industry, our progress would certainly have been much slower and our achievements fewer. Twenty years ago the industry was sceptical as to the Board's value, but the work of these stations has proved that value, and now we count on, and receive, industry's full support.

There is corresponding constant co-operation between the officials of the Department of Fisheries and the scientists of the stations. The integration of effort between industry, government officials and scientists reflected in this, as in the deliberations of their representatives on the Board itself, increases the chance of success in all our endeavours.

REFERENCES

The material presented in this paper is based chiefly on the Annual Reports of the Board to the Minister of Fisheries, 1929–1945 inclusive (specific references being indicated by 'A.R.' and the year), and the 'Progress Reports' issued at both coasts three or four times a year for the information of the industry and the fishermen. Results of the fundamental investigations have been published in the 'Journal' of the Board, or in its 'Bulletins,' one or two of which have been specifically referred to.

ANIMAL GENETICS IN NEW ZEALAND

By F. W. Dry
(Massey Agricultural College)

Animal Genetics in New Zealand so far means inheritance in farm animals. Statistical work will be dealt with first, Mendelian second, and then examples will be given of problems of wide bearing, some of them on the borderline of genetics, likely to claim increasing attention from livestock research workers.

STATISTICAL STUDIES OF BREEDING

Dairy Cattle

Ward (1) has supplied a numerical background for dairy cattle improvement. His analysis of the causes of death and culling is the envy of those who work with sheep. He has made us familiar with the smallness of that part of the excess or defect of the yield of the dam, in contrast with the herd average, which reappears in her daughter. His figure is from 15 to 20 per cent. Ward has emphasized the danger of attempting to give a bull a single index figure for butterfat worth. He prefers to judge sire survey results from an ' expectancy ' table, which (1945) may be abbreviated as follows :

Maturity equivalent production (lb fat)

dams . . .	270	300	330	360	390	420
daughters . .	294	312	329	349	369	386

Ward is able, however, to attach appreciable importance to life-time merit cows, as well as to the sons of proven sires. Bulls sired by proven bulls out of cows of sustained merit will clearly figure prominently in the gradual cumulative improvement which is confidently expected.

Ward's demonstration of the low relation between dam and daughter is based on figures which are averages of several lactations. This makes it likely that environmental factors, somewhat elusive, it is true, which act early in life, produce an enduring effect. Besides making progeny testing the great hope, Ward's work shows the need for research in this non-genetic direction.

In a recent paper Ward has shown that butterfat percentage is much more strongly inherited than milk yield. While he advises caution in applying straight selection for high test, he warns against ignoring low fat percentage in attempting to build up high levels of butterfat production.

Hamilton (2) has recently made an analysis of the causes of the increase

in butterfat production per cow in New Zealand since 1919–1920. His figures are :

	estimated share of improvement (lb)	percentage of total improvement
selection of daughters from higher producing dams	2	3·3
culling of young low producers . .	8	13·1
change in breed composition together with grading up through the use of pedigree sires	16	26·2
improvements in plane of nutrition .	35	57·4
	61	100·0

Non-genetic factors are the most important. The genetic improvement resides largely in the replacing of Shorthorn by Jersey ' blood,' the average Jersey producing about 15 per cent more butterfat than the average Shorthorn.

SHEEP

In his capacity of Wool Metrologist, McMahon (3) works for efficiency both by controlling the environment and by breeding. His results from survey work, in which, for example, he finds that coarser fleeces tend to be more profitable, owing to considerably greater weight, on better country and finer on poorer country, will be passed over with little mention. Production characters, inherited in complicated fashion, are much influenced by non-genetic factors. From comparisons of related sheep he finds that wool count, head shape, and the medullation of persistent fibres, are inherited moderately strongly, while fleece weight, fleece character and mutton type are weakly inherited.

Weak inheritance of economic characters calls for progeny testing, which is well under way at the two agricultural colleges and at the Ruakura Animal Research Station. McMahon is able to conclude that quite spectacular improvements can be obtained in this way. The progeny of one ram averaged 2·2 lb more wool than the average progeny of all sires used in the flock. McMahon calculates that a short succession of progeny-tested sires will quickly raise production by a very well worth while amount, assuming the gains to be additive. Whether the gains will be less good, or still better thanks to geometric interaction of genes, remains to be seen.

There is a parallelism between McMahon's work on fleece weight and Ward's on butterfat yield in that a quite good relation exists between the fleeces grown by the same sheep in different years. Hoggets clipping one pound above average will produce half a pound more wool than average at each subsequent shearing. Again we are entitled to conclude that something non-genetic acting early in life, produces a lasting effect. Statistical studies of the inheritance of fleece weight thus suggest that wool growth might be made greater throughout life by appropriate treatment in early days, perhaps even before birth.

Constructive breeding with sheep is more difficult than with dairy cattle, for the sheep-farmer must have less of a single-track mind than the dairy farmer. Nevertheless, in sheep as well as in cattle, the newer appreciation of realities promises progress. In a stud flock in which Waters had helped the breeder to start progeny testing, McMahon found a striking example of the superiority of weighing what can be weighed and recording eye judgments on paper. An expensive sire prized by his owner for what he was in fleece and body was the father of six sons rated high on visual appearance who themselves were used in the flock. The progeny of the sire and the average progeny of his six sons were found to be significantly below the standard of the flock for fleece weight, mutton type, and breed type. In the same flock the sire who ranked best on progeny test had been left idle for a season. When his worth was recognized he was used widely with success.

Twenty years ago Crew stressed the value for practical breeding of a genetically informed point of view. Thanks to this, phenotype and paper pedigree are becoming a little less easy to sell. Moreover, progeny testing sheep brings home the difficulty of selecting for several production characters at once. The wastefulness of selection for fancy points is becoming the easier to notice. 'Let us throw overboard,' says McMeekan (4), 'as much as possible of the supercargo by placing our emphasis upon utility characters, the need for accurate measurement of performance, and the absolute necessity of judging an animal on the way it produces and breeds and not on its appearance.'

MENDELIAN BREEDING

Lethal factors

Only a few are known, and research workers are realizing that more is likely to be achieved by aiding the multiplication of genes for production higher than average than in hunting lethals. Mr John M. Ranstead (5), who for many years has taken an intense interest in genetics, and who has started to remove the horns from his milking Shorthorns, was very interested in the birth of an odd Parrot beak calf in his inbred herd. He was, however, a little unhappy to think he might have sold this gene to some of his clients, and this led him to choose 'Should a Breeder Tell?' as the subject of the Presidential Address which he delivered to the New Zealand Animal Production Society at its First Conference. Dr H. E. Annett (6) has reported split-ear, accompanied by cleft palate, in Tamworth pigs. Both these lethals are clearly simple recessives. So, we are safe in saying, is Photosensitization in Southdown sheep, which may rank as a sub-lethal, upon which breeding experiments have been under way at Ruakura for several years. In one stud flock it seemed that the evil luck of using three rams heterozygous for the factor had raised the incidence of susceptible lambs nearly to the theoretical limit of about 14 per cent.

At the Massey College, Palmerston North, a highly priced Southdown ram sired numerous lambs almost exactly a quarter of which had distorted brains and behaved during any brief career in abnormal fashion. It seems most reasonable to regard this ram as heterozygous for a new sub-lethal mutant which comes to expression in only half the lambs which receive it.

Pink bones in pigs

Clare (7) and Stephens (8) find Pink bones in pigs to be inherited, very likely as a simple dominant, though the facts which it was possible to secure remind us how difficult it may be to decide on all the data which it is sometimes feasible to secure from livestock whether a simply inherited character is dominant or recessive. Claire's biochemical work has interest as physiological genetics.

Colour inheritance in pigs

The Large White-Tamworth project (Massey Agricultural College, Lincoln Agricultural College and Ruakura Animal Research Station) is aimed at combining desirable qualities from both breeds, notably the length and hams of the former with the colour of the latter which gives protection against the sun. The range in colour in crossbreds of the second generation and other matings may at first sight look bewildering, but it soon became apparent that White is a simple dominant to Coloured, though some pigs essentially white have a sprinkling of red fibres. Cross-bred coloured pigs generally have black spots, and on the average the amount of black spotting is greater in paler reds. Some coloured pigs may, so to speak, be regarded as reds which are so pale as not to be red at all, these being black-and-white. There is good reason to believe that the difference between deep red and black-and-white depends on only a small number of genes, perhaps no more than two main modifying factors. This means that, if further crosses are made to the Large White in order to pile up factors for good carcass, it should not be unduly difficult to hold the factors for deep red derived from the Tamworth. It is likely that white pigs with an abundant sprinkling of red fibres are, firstly, heterozygous for the dominant factor for White. Secondly, there are grounds for regarding white with many red fibres as well endowed with the modifying factors which make coloured pigs a good red shade. If these things are true they are likely to help in constructive breeding programmes. It should be mentioned that an occasional white pig with a very small number of red fibres has proved to be a homozygote.

Auto-sex-linkage in fowls

E. P. Neilsen (9) has demonstrated to the dairy farming community by his sustained breeding work with fowls how varied in characterization may be the descendants of the same ancestors. Strikingly different stocks, all extremely closely inbred, trace back to the same foundation pair, a White Leghorn and a Bantam. Two of these stocks are auto-sex-linking. They are barred, the males being very much lighter than the females both at hatching and when feathered. Clearly the factor for barring came from the White Leghorn, and so very likely did the one or more postulated modifying factors which allow the pair the barring genes of the male to reduce pigmentation much more than the one gene of the female. These stocks were not bred to practical ends but they point to ways in which auto-sexing stocks good in production might be developed. The cost of poultry food being high, such stocks would be acceptable in New Zealand.

Morphological characters of the sperms of dairy bulls

Blake has accumulated data over very many years on structural abnormalities in the sperms of bulls, notably re-turned tails and narrow heads. When either is abundant fertility tends to be poor. Further, it seems likely that the factors, one or more for each character, reside on the Y-chromosome (unpublished communication). Inheritance in the direct male line is suggested, with the factors not invariably coming to expression. After the facts have pointed to this mode of inheritance it seems just what one would expect of the Y to carry genes concerned with fertility. On the practical side the danger of handing down poor fertility in the direct male line should especially be watched in these days of artificial insemination.

N-type sheep

These sheep, of Romney origin, which are numerous at the Massey College, have fleeces in hairy Mountain style, the birthcoat being loaded with large birthcoat kemps, the halo-hairs. They are named after Mr N. P. Nielsen, who gave the first N-type ram to the College. N-type is inherited, in different stocks, as a simple dominant and a simple recessive. The genetic relation between Dominant-N and Recessive-N is under investigation. It is thought that these two factors, together with Non-N, form a series of multiple allelomorphs. It is suspected, further, that the recessive factor can change to become dominant. In a third stock, to be mentioned later, N-type is inherited in multifactorial fashion.

Almost all N-type rams are horned, aid to horn growth being regarded as another activity of the gene or genes conditioning N-type coat. Dominant-N ewes, it is concluded, are at least usually horned when homozygous, and polled about nine times in ten when heterozygous. Recessive-N ewes so far have been polled. In seeking to build up a dominant stock homozygous throughout the horns of the ewes are useful.

This work began as a study of one aspect of hairiness, but the fundamental significance of a genetical situation not looked for in a large domestic animal came to eclipse hairiness. Recently new born N-type skins have attracted commercial interest as possible furs. Well marked curling is desired, and the beauty is deemed to be increased by clipping the birthcoats fairly short. If breeding N-type becomes in this way a practical enterprise much that has been found out these last dozen years will have direct bearing on fur production.

OTHER MAJOR PROBLEMS OF LIVESTOCK GENETICS

Nature and nurture

Buchanan Smith pointed out some years ago that 'is it inherited?' is the first question to be asked in livestock genetics. To this end McMeekan has put Romney type ewes of good conformation and ewes of bad conformation, in particular long in the leg, to the same Southdown rams, to ascertain to what extent selection of the ewes counts in such fat lamb breeding. The dominance of Southdown genes is of course also involved.

As already mentioned, McMahon has concluded, from data from parents and offspring, and data from the same sheep in different seasons, that hairiness (of persistent fibres) is moderately inherited, which means that non-genetic factors have considerable influence. Differential shearing experiments, of which Rudall's were the best, have shown that the balance determining medulla or no medulla is delicate. This is neatly demonstrated by the ' invasion effect.' Hairy-tipped lambs were partly shorn soon after medulla formation had ceased. Shearing, probably by cooling the skin, evoked medulla formation in the region of many fibres grown following the shearing on the shorn area, while no medulla appeared at the same time on the adjacent unshorn area save a little just within the boundary of shorn and unshorn areas of some lambs.

Identical twins are favoured material for attempts to learn what is conditioned from within, what from without. A goodly company of identical twins, mostly heifers but a few bulls, have been got together at Ruakura. Early in this work one method of diagnosis was added to those borrowed from Germany and Sweden. When the fibres of corresponding tufts of hairs from the two calves are spread out one by one, roughly in order of size, the eye of the hair-splitter can nearly always, though not invariably, detect differences in detail between the hairs of twins judged fraternal on all the evidence, but no differences have been observed between the hairs of twins classed as identical. For practical purposes, however, Hancock does not spend time on hairs. Although Jersey calves are much more alike than Jersey cows, he is able to reach a decision, like Newman with human twins, by looking hard at the two calves for a very short time. In some sets of identical twins corresponding hair whorls are direct images, each of the other, both for example being anti-clockwise spirals. In other sets of twins the whorls show mirror-imaging. One wonders whether the first kind will agree in performance more closely than the second.

Blake has examined the sperm pictures of one set of identical twin bulls and finds them arrestingly alike (personal communication). This strengthens his belief that morphological characters in the sperms of dairy cattle are strongly inherited.

Inheritance of functional characters

In reviewing the state of the science in 1932 Morgan named the inheritance of physiological characters as of special importance for the future of genetics. In livestock perhaps even more than in laboratory animals is attention forced away from mere symbols for genes, and directed to the functioning of the animal body secreting milk and growing wool.

In Wool Zoology the way follicles work has so far been largely inferred from observation on structure and development. A great part of the fleece is founded before birth, and some fibres start to grow much longer before birth than others. The earliest starters are generally comparatively coarse and medullated at a distance only short from the extreme tip point. The later starters have finer tips not medullated. ' First come, first served ' is a common principle in mammalian coats, but one to which the sheep provides a striking exception. Very commonly many fibres, which soon after starting look as if they would continue robust as they grow, become finer and medulla formation may stop. A check has struck the root. This

concept of the pre-natal check is the central idea in the fibre type work at the Massey College.

After birth it commonly happens that many fibres that show in their tips the restrictive action of the pre-natal check become much coarser and are medullated. Often, however, some fibres that start to grow comparatively early before birth are fine and non-medullated in the region grown following birth, while fibres that begin to grow a little later are coarser and medullated. In the fine fibres just mentioned we see the enduring effect, after birth, of the pre-natal check, which often hits some early starting fibres harder, not only than fibres starting still earlier, but also, harder than fibres starting a little later. This is the exception to 'first come, first served.' The pre-natal check then appears to be at its most intense at a stage when comparatively early starting follicles are in a vulnerable state. Follicles founded before them are well enough established to stand up better to the check ; follicles founded later are not so exposed to this check. It is concluded that the timing of the onset of the check, its intensity, and the timing of its subsiding, all vary. These variations find expression in the differences in fibre type arrays, that is, in the characterization, in pre-natal and post-natal regions, of the fibre types arranged in order of their time of beginning to grow. Fibre type array is strongly inherited.

As to the nature of this checking force, we can only make suggestions informed by some acquaintance with pre-natal development. At a certain stage new follicles may be founded proportionately so much faster than the skin expands that they cramp one another. Or slackening of the rate of skin expansion, irrespective of density may be crucial.

The pre-natal check, which from the literature, would seem to occur also in the Angora Goat, is a very rare phenomenon in mammalian coats. It affords an intelligible explanation of why most fibres in the sheep's fleece go on growing indefinitely. Consider this contrast between two early starting fibres alike in pre-natal form. One may be coarse and strongly medullated in its post-natal region, cease growing after some six weeks, and shortly be shed, thus being a kemp. The other, thanks to the pre-natal check, may continue fine after birth and grow without ceasing so long as the animal lives. So indeed may fibres of the same sort which become coarse after birth, but the more lusty a fibre type in its pre-natal region, the more freely does that type shed. Shedding thus appears to be a matter of vigour. A follicle that sprints becomes tired, but a follicle whose vigour is damped never exhausts itself. That force which causes the fleece to grow for ever is of vast economic importance.

When genes are recognized the chance is presented to study their mode of working, as in Claire's chemical work on Pink bones. Dr Nancy Galpin studied pre-natal development in ordinary Romney sheep. Miss Janet Ross has made a preliminary parallel study for N-type. N-type lambs have a much more bulky birthcoat than Non-N, and the fibre type array indicates a very weak pre-natal check. Miss Ross's work makes it likely that the two contrasted coats begin to grow at the same time, so that the difference does not lie in an earlier start in N-type, but in more vigorous building of the coat once development has started.

EARLY RECOGNITION OF CHARACTERIZATION

Early developing characters tend to be strongly inherited. Head shape in sheep is more strongly inherited than mutton type. Not only are abundance of halo-hairs and fibre type array strongly inherited, but so is the size of the sickle-end of sickle-fibres, fibres frequently shed, and so kemps, not so big as halo-hairs. This is quite a minute detail. From the examination of a considerable number of lamb specimens sent from England it is possible to congratulate Wensleydale breeders on building up a breed characterized by a fibre type array having specialized features, including complete absence of large or medullated sickle-ends. Wensleydale wool is in several respects specially even, and so one may wonder whether evenness may thus be recognized very early from the fibre type array—which is strongly inherited—and whether selection on fibre type array might be a practical matter if conspicuous evenness be desirable enough to warrant this attention.

N-type sheep, so enormously kempy in their birthcoats, may grow much or little kemp in the same follicles in later life. In Mountain sheep such birthcoats are desired. They are thought to be a protection against hard weather, and they are generally the forerunner of the kind of later fleece, with long hairy fibres to run off the rain and abundant fine fibres for warmth, advantageous in tough conditions. It is generally preferable for manufacturing that there should be little kemp. From details observed early Miss Ross is able to foretell the later kemp situation with a large measure of success. This she can offer as some acknowledgment of the mass of truth imported into New Zealand from over the seas.

RAPID ROTATION OF THE GENERATIONS AND GEOMETRIC INTERACTION OF GENES

Dickerson and Hazel have recently shown that rapid rotation of the generations and straight selection will sometimes give more rapid advance than progeny testing owing to delay in waiting for the offspring to be born and reach the minimum age at which they can be judged. A small stock of N-type sheep, with halo-hairs ten times as abundant as in the foundation animals, has been built up gradually but quickly by selection. The generations have been rotated very rapidly on the male side. From 1939 onwards five rams have been used, each after the first the son of his predecessor. In this Multifactorial-N stock the several genes, which are probably not very numerous, appear to interact in geometric fashion, multiplying one another's effects.

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GENETICS

(Plant breeding and genetics)

By Dr O. H. Frankel, M.Agr.Sc.
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ECONOMIC BREEDING PROGRAMMES IN NEW ZEALAND

The following is a list of the plants on which breeding work is now progressing or projected, together with the principal breeding aims :

Agricultural crops

Agronomy Division, D.S.I.R.

Oats . . .	High yield, high milling and feed value, resistance to lodging ('Resistance' used as stiff-strawed parent).
Barley . . .	High yield and malting quality ; resistance to lodging ('Wong,' 'Major' and 'Kenia' used as stiff-strawed parents).
Field peas . .	Partridge type with shorter straw, earlier maturity and improved grain quality.
Garden peas . .	Improved early type ; mosaic-resistant 'Greenfeast' type ; improved canning type.
Rape . . .	Aphis resistance, by crossing with the resistant swede 'Dryland.'
Swede . . .	Higher quality 'Dryland' type.
Kale . . .	Greater leafiness, from crosses Chou Moellier × Thousand Headed Kale and cabbages.
Lucerne . .	Development of satisfactory grazing type from *Medicago sativa* × *M. glutinosa*.
Linen flax and Linseed	Resistance to rust, wilt and browning, using 'Rio' as resistant parent.
Potatoes . .	Resistance to late blight and frost (using South American forms) ; development of virus-free forms from standard varieties.
Lupins . . .	Higher production, greater adaptability and resistance to shattering in sweet lupins.
Maize . . .	Development of double cross hybrids ; resistance to head smut and cob rot.
Vegetables . .	Proposed development of improved types for local conditions.

Wheat Research Institute

Wheat . . .	Highest yield and baking quality ; resistance to lodging and shattering.

Botany Division

Phormium . .	Quantity and quality of fibre.

Tobacco Research Station

Tobacco . .	Mosaic resistance.

PASTURE PLANTS

Grasslands Division, D.S.I.R.

Perennial rye grass .	High yield, wide seasonal spread of production, persistency, resistance to leaf rust (*P. coronata*) ; resistance to blind seed disease (*Phialea temulenta*).
Short rotation ryegrass	Combination of desirable features of Italian ryegrass with those of perennial ryegrass ; rapid establishment, high winter and early spring growth and palatability of Italian ryegrass with a high degree of the persistency of perennial ryegrass.
Italian ryegrass .	High yield especially in winter and early spring, greater persistency than annual.
Western Wolths ryegrass	Annual with most rapid establishment and highest possible production especially in winter.
Cocksfoot . .	High production, rapid recovery from grazing.
Timothy . .	Greater vigour, tillering, leafiness and lower winter-dormancy.
White clover . .	High yield, wide seasonal spread of production, persistency.
Red clover . .	Two strains (*a*) Broad red clover—high yielding hay type, (*b*) Montgomery red clover—dense, persistent, pasture type.

Lincoln College

Cocksfoot . .	Improved pasture types.

MATERIAL AND METHODS

In agricultural crops other than wheat, selection from, or crossing between, a relatively narrow range of New Zealand produced or imported varieties is being applied.

In wheat a collection of over 3,000 lines has been tested systematically for its usefulness for constructive breeding. A number of lines from this collection have been used. A selection, which was named Tainui, from a mixed sample of Portuguese origin, crossed with our standard variety, Cross 7, recently yielded a line which in protein quantity and quality far exceeds any of our commercial wheats, and even Marquis. Its agronomic

potentialities under New Zealand conditions are not fully tested ; yet it is already clear that this line is likely to prove a most valuable crossing parent, in New Zealand and perhaps elsewhere.

In pasture plants, a hundred years' natural selection has provided a host of genotypes available for selection. In spite of marked progress in recent years, this store is not nearly exhausted. Further selection of outstanding plants and their utilization in strain building is expected to raise productivity of most pasture crops for some time to come. Indigenous material is also being used successfully for constructive breeding. L. Corkill recently produced a short-rotation ryegrass from a cross of selected lines of perennial and Italian ryegrass. He has now found individuals which are resistant to the blind-seed disease of ryegrass (*Phialea temulenta*) and these have been crossed with more productive types.

From the foregoing it is evident that, with the exception of wheat, the material used in New Zealand plant breeding is confined to indigenous sources, to well established old importations and to a narrow range of recent ones ; and that with the exception of the genera *Brassica* and *Lolium*, single plant selection, strain building and intra-specific crossing have been the methods used so far.

Two developments are likely to occur in future, once the possibilities of material and methods, as used at present, approach exhaustion. The first is an extension of the material used, by systematic introduction of new varieties and species for constructive breeding. The utilization of the Empire potato collection comes to mind ; but there is scope for a search for useful new material in nearly every crop. It is unlikely, for example, that a systematic search for oats with high milling properties should not yield better parents than the chance introductions of the past.

The second development which is likely to take place is the extension of plant breeding activities to new crops. All the major agricultural and pastoral plants are now being bred, and work on some of the minor ones is under consideration. Horticultural plants, with the exception of peas and tomatoes, have so far not been subjected to selection and breeding by professional plant breeders. Forest tree breeding is another, and probably more important, gap in plant breeding activities in New Zealand. In view of the likelihood of extensive tree planting in the coming decades, forest tree breeding appears to the writer perhaps the most urgent need in the field of applied genetics in New Zealand.

GENETIC AND CYTOLOGICAL INVESTIGATIONS IN NEW ZEALAND

Much of the genetic work done in New Zealand has direct bearings on problems of economic significance. Little cytogenetic research has been done on the indigenous flora. The work of Cockayne and Allan on hybridism in New Zealand has scarcely been followed up by the geneticist or the cytologist. Even the chromosome numbers of the great majority of New Zealand plants are unknown. Some were determined by the writer and by J. B. Hair. (Mostly unpublished).

The following is a list of genetic and cytological investigations which were recently concluded or are now progressing :

Wheat . . .	A series of studies on methods of selection and their effects (S. W. Boyce, L. G. L. Copp and O. H. Frankel).
	Biometric and genetic population studies on different generations from the same cross (T. P. Palmer).
	Inheritance of weight of grain and its relation to other yield characters in tetraploid and hexaploid species. (S. W. Boyce and L. G. L. Copp).
	Inheritance of shattering of grain. (L. G. L. Copp and O. H. Frankel).
	Cytogenetic studies of fertile and partially sterile A-type speltoids. (O. H. Frankel and A. S. Fraser).
	Spontaneous chromosome fragmentation as a regular, high frequency phenomenon. (O. H. Frankel).
Rape . . .	Attempt to double chromosomes of kale ($n=9$) for crossing with rape ($n=18$). (R. A. Calder and A. D. Stewart).
Tomato . . .	Further study of heterosis effects. (A. D. Stewart).
White Clover . .	Inheritance of Cyanogenesis. (L. Corkill).
Perennial ryegrass .	Progeny testing by open pollination versus diallel crossing as a basis of selection for quantitative characters. (L. Corkill).
Hebe and Veronica .	Chromosome studies of many New Zealand species and varieties. (O. H. Frankel).

As stated above, the majority of these studies have a background of economic utility. Some are designed to supply breeding material, others information—on the constitution of populations used for selections, on selection methods, on the inheritance of characters of economic significance, on chromosome or gene mutations occurring in breeding material.

These investigations are conducted by workers whose principal task is economic plant breeding. So far there is no one, either at the university and agricultural colleges, or at the various plant breeding organizations, whose chief task is research in genetics. One consequence of this deficiency is the lack of teaching facilities for plant and animal geneticists. If genetic research—and, ultimately, plant and animal breeding—are to advance, research and teaching in genetics should, in the writer's opinion, receive greater support in the years to come.

PROPOSALS FOR EMPIRE CO-OPERATION IN PLANT BREEDING AND GENETICS

Plant breeding to a large degree is tied to the soil and climate for which it works; and although many varieties are found suitable for a wide geographical and ecological range, co-operation in breeding schemes has its limitations. There are two fields, however, in which widest co-operation is not only possible, but even essential: the provision of material, and the acquisition of basic knowledge.

(a) Plant collections

In its report on the Imperial Agricultural Bureaux, 1943, a committee under the chairmanship of Lord Hankey recommended the establishment of plant collections distributed throughout the Empire, conducted and used on a reciprocity basis. New Zealand delegates to a number of international and Empire conferences have stressed the need for such action; and from the first part of this paper it is evident that in years to come New Zealand plant breeders are likely to be as much in need of the widest range of plant material as those in any other Empire country.

The difficulties of the proposal—in organization, collection and maintenance of material, staffing, finance—emphasize the need for slow and careful progress. Yet even at the inception it seems necessary to visualize the aims and objects, so that the foundations shall be laid in such a way as to allow future growth.

The following considerations are proposed in connexion with the establishment of Empire plant collections as proposed in the Hankey Report (pp. 17–18):

(i) *The collections should aim at complete coverage.* This may require collecting expeditions, in addition to the assembly of material held by different stations. It should further include new varieties, and, wherever possible, even breeding lines with specific valuable characteristics. Although it may be necessary for technical reasons to disperse a collection for any plant by locating sections at different stations, it is suggested that such a division should be on a systematic rather than on a chance basis according to the material which happens to be held by any one station. In cross-pollinated short-lived species, which present the greatest difficulty in maintenance, a system of exchange of lists between stations, as suggested in the Hankey Report, may be the only practicable method.

(ii) *The collections should be situated in localities where a maximum range of any one plant—or section—can be successfully raised.* New Zealand has already offered to accommodate and maintain a central wheat collection, not for the reason that the Dominion is particularly interested in this crop, but because it has been found that here every type of wheat can be grown successfully and easily at one station, whilst major difficulties are experienced in growing certain wheats in most other parts of the Empire.

(iii) *The collections should be classified as comprehensively as possible.* The more is known about their components, the more useful will be collections which, for many plants, are more likely to consist of thousands than of scores of samples. Classification in fact should render a full use of the

collection possible to any station, even those with relatively small resources, which would find it impossible to grow, test, and, therefore, to utilize hundreds or thousands of nondescript lines. Certain types of classification could be conducted at the central stations, e.g. systematic classification, some phenological observations, disease tests or technological evaluations. Others could not be carried out there, since the central stations should be chosen so as to avoid rigours of climate or severity of insect or disease attacks. Such observations could be conducted by stations receiving plant material and should be recorded by the central stations, these acting as clearance centres for information as well as for material. Co-operation, if extended to classification, would prevent a great deal of duplication and therefore save work, time and money.

(iv) *The establishment of co-operative plant collections in various parts of the Empire seems to demand a central organizing authority.* Its functions might be to initiate and organize the central stations ; to assist in the exchange of material and information within the Empire and with foreign countries ; to organize collecting expeditions.

(*b*) Study of phenomena fundamental to plant breeding

Plant breeders are well aware of the desirability of transforming their ' art ' into a ' science ' to a greater degree than has been the case so far. Recent advances in cytology and genetics have greatly increased our knowledge of variation between and within species ; advances in the genetics of quantitative characters now extend a promise of a fuller understanding of the types of variation which are of special concern to the breeder. With increasing knowledge of the manner of inheritance of economically valuable characters goes an improvement in the technique of selection. It is now proposed that active encouragement be given to researches on fundamental problems which are likely to be of great value to economic plant breeding. Some of the subjects in view are listed below :

Studies of plant populations used for breeding purposes, of methods of selection and of their effects.
Studies of the mode of inheritance of quantitative characters.
Studies of the physiological nature of quantitative gene differences.

In proposing that work on the lines suggested be carried out in one institution especially fitted for the purpose, it is not intended to suggest that research on problems fundamental to plant breeding should be wholly centralized. Indeed the writer believes that without some pure research, applied work is bound to stagnate. Yet the nature and difficulty of the work, the many facets it presents, the cost of equipment for physiological work, all argue for a concentrated effort at an institution specially suited for fundamental work in genetics and physiology.

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GEOPHYSICS

(Seismological work in New Zealand)

By R. C. Hayes

EARLY WORK AND DEVELOPMENTS

Prior to about the beginning of the present century, seismological research work in New Zealand was based entirely on non-instrumental records—i.e. the perceptible effects of earthquakes, collected from various parts of the country. This work was carried out originally in early days largely by Hogben and Hector. The data were obtained by means of a reporting system, with the co-operation of Post Office officials ; and later, by lighthouse keepers also. Thus, a network of earthquake reporting stations was established throughout the country. This has been amplified in more recent years, and in spite of the increase in instrumental recording, it remains a most important section of the seismological work in the Dominion.

About 1900, two Milne seismographs were installed in New Zealand, as part of a world-wide system of seismograph stations instituted by Milne, under the auspices of the British Association for the Advancement of Science. One of these seismographs was installed at Christchurch Observatory, and the other was operated by Hogben, first at Timaru, and later at Wellington. After Hogben's death in 1920, his seismograph was taken over by the Dominion Observatory, which then became the Central Seismograph Station. In 1923 two Milne-Shaw seismographs were installed at Wellington Observatory.

In June 1929 the large earthquake occurred in the Buller region of the South Island ; and this gave a marked impetus to seismology in the Dominion. New seismographs, and other equipment, were obtained, and installed at both Wellington and Christchurch Observatories. An additional recording station was established in both the North and South Islands. In February 1931, the Hawkes Bay earthquake, probably the Dominion's most momentous seismic event of recent years, was followed by improvements in the earthquake recording system, including the establishment of additional stations in both Islands.

During the past decade, the network of seismograph stations has been extended further, and the equipment improved, so that at the present time, comparatively small shocks in the New Zealand Region can be located with reasonably good accuracy.

RESEARCH

General

A considerable amount of research work on New Zealand earthquakes was carried out in the early days by Hogben and others, but the result

were restricted by the limited accuracy of the data. Only during the past fifteen years or so have there been adequate data for attacking such problems as local wave velocities and crustal structure.

Bastings carried out an extensive investigation of the 1929 Buller earthquake, mainly from seismograph records collected from all parts of the world. Bullen also, has carried out investigations on various aspects of New Zealand seismology, including the study of special earthquakes and their implications on the structure of the Region.

Wave velocities and crustal structure

The important problem of local wave velocities and crustal structure has been undertaken by several seismologists. An attempt at a solution was first made by the writer in 1935, but the data available then were not of high accuracy, and in consequence the results were only approximations. Later, Bullen and Jones carried out similar investigations, independently, using more accurate data. They confirmed the writer's earlier approximate results ; i.e. that the crustal structure in the New Zealand region has features in common with that of other regions, and particularly with those of the Japan region. With the accumulation of more observational material during the war years, this problem is again awaiting revision.

Deep focus earthquakes

Of special interest is the phenomenon of deep focus earthquakes. It was not until about 1930 that the occurrence of earthquakes at depths of several hundred kilometres below the earth's surface was established definitely. Soon afterwards, it became evident that a considerable proportion of the earthquakes in the New Zealand region had deep foci.

With increasingly accurate seismic data in recent years, the characteristics of these deep shocks have been closely studied. The distribution of their epicentres in relation to the shallow shocks has been found to correspond with that in other regions round the Pacific border where deep shocks occur ; i.e. that the deep shocks occur on the 'continental' side of the general seismic zone. Another interesting feature of the distribution of deep focus epicentres is their coincidence with the lines of volcanic activity. This feature is common to other regions as well as to New Zealand. No satisfactory theories have yet been advanced to account for the mechanism giving rise to earthquakes at such great depths, in some cases as much as 600 or 700 kilometres ; nor for their influence on surface volcanic activity.

The writer has also investigated the depth distribution of earthquake origins in the New Zealand region, and the results have shown that in all regions the limiting depth at which shocks originate is well marked. Maximum depths under the country as a whole vary from about 15 to 20 km., up to 370 km. Moreover, the lines of maximum depth follow definite patterns which evidently coincide with a marked change in the condition of the sub-crustal material.

The deep shocks in the south-west Pacific region generally have also been studied, with particular attention to their distribution, and characteristic features of their records which lead to reliable determination of depth.

Regional seismicity

The problem of the seismicity of New Zealand and the general distribution of earthquake effects has been thoroughly investigated. This is a matter of great practical importance to the community. The results so far have been based mainly on non-instrumental data, as the period covered by adequate seismic records is very short. Even the non-instrumental records extend back only about 110 years : a very short period, geologically.

These investigations have led to a division of the country into four main regions, each having a different degree of seismicity. Broadly, it may be said that the central parts of the Dominion have the highest seismicity ; and that no part can be considered entirely free from seismic disturbances.

Ground tilting

For a number of years, tilting has been recorded at Wellington Observatory and at the Auckland Seismograph Station. The records have been studied with the object of obtaining some indication of pre-seismic tilting. The results failed to reveal any definite connexion between tilt movements and the occurrence of local earthquakes. The conclusions reached were similar to those found in California, i.e. that the tilt records were dominated by movements due to meteorological causes, such as temperature changes, loading due to precipitation, etc. No effects due to tidal loading were found.

Earthquake intensity and magnitude

In addition to the use of arbitary non-instrumental scales for determining earthquake intensities, local earthquake intensities are now measured in terms of an instrumental magnitude scale, similar to that used in California. Owing to the fact that the standard short-period seismometers employed in New Zealand are similar to those in California, the California magnitude scale could be applied directly to the New Zealand records. The magnitude results in New Zealand are in good general accord with those in California.

Engineering seismology

Up to the present, very little engineering seismology has been done in New Zealand, but there is an increasing demand by engineers and architects for more precise data on the vibration of the ground and of structures ; and it is evident that more work of this type will have to be undertaken in the near future.

Microseisms

Some work on the investigation of microseisms has been done both at Wellington and Christchurch Observatories. High intensity of microseisms in general appears to coincide with the passage of atmospheric cold fronts.

Some particularly interesting comparisons between microseismic activity at Auckland and Wellington showed a time difference between the peaks of high intensity, which in many cases coincided with the passage of atmospheric fronts at the two stations.

Future problems

In addition to the demand for vibration work, a number of other problems in seismology are awaiting either investigation or revision.

Owing to shortage of staff and other difficulties, practically no research work was carried out during the war years, but essential routine work, including the maintenance of nearly all the seismograph stations, was continued. The monthly provisional seismic bulletin for all New Zealand stations was published promptly up to date right through the war period.

With the extensive accumulation of seismograph records, there are now sufficient data available for a revision of local travel times and a more accurate knowledge of structure in this region. Revision of travel times is a particularly important problem, since the results naturally lead to more accurate location of earthquake origins.

Some of the other research problems awaiting attention are: (*a*) periods and accelerations in local earthquakes; (*b*) study of subsidiary phases in records of deep focus earthquakes; (*c*) correlation of instrumental magnitudes with surface intensities estimated on arbitrary scales; (*d*) classification of record patterns of shocks from different regions.

Since the termination of the war, experiments have been commenced on the application of electronic methods to the operation of seismographs and their subsidiary apparatus.

MODERN SCIENTIFIC AIDS TO FISHING OPERATIONS

By A. E. Hefford
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The above heading is much wider than that which appeared in the draft programme for item 4 (ix) ('Aerial survey and the fishing industry'); but, since criticism of that list was expressly invited it may be pointed out that, so far as New Zealand's fishing industry is concerned, discussion under that heading would narrow down the subject to very small limits and would be of little immediate practical value.

The reason is that the use of airplanes, which have been employed off the European and American coasts and, in a tentative way, more recently off the Australian coast, is only of service in connexion with a pelagic fishery—e.g., for herring, mackerel, sardines, tuna, etc., such as occur in shoals which on occasions appear at the surface of the open sea. At the present time there is in New Zealand no pelagic fishery, properly so called, such as the drift-net and tuck-net fisheries of Britain and the various modes of purse-seine netting practised in North American and Mediterranean waters.

There are various species of pelagic fishes occurring in our seas, but up to the present they have only been fished for when they arrive in close proximity to the land. The most important example is the sardine or pilchard fishery which has been developed of recent years in the Marlborough Sounds on the 'south' (more correctly the west) side of Cook Strait, for which small purse-seines are used, generally with the accessory fish-attracting light. Other surface-shoaling species which occur in our coastal waters are kahawai (*Arripis trutta* (Forster)), trevally (*Usacaranx lutescens* (Richardson)) and horse-mackerel (*Trachurus novaezelandiae* (Richardson). Members of the tunny family—bonito (*Katsuwonus pelamis* (Linnaeus)) and albacore (*Germo germo* (Lacépéde)) are also known to occur and at times have been reported to have appeared in large schools off the N.E. coast of North Island. Kahawai, trevally and horse-mackerel are caught in large seines on the open coast but more frequently when they enter narrow bays and harbours. Bonito and albacore together with larger tunny species are taken in small quantities by trolling. Some observers have been impressed by their apparent abundance, as judged by the area of observed shoals, and consider that there should be a commercial future for these kinds as fish for canning. A purse-seine fishery was commenced at Tauranga in the Bay of Plenty during the war but has not met with success.

It is conceivable, if not probable, that scouting by airplane would be of practical use for the purpose of saving time and fruitless steaming as an ancillary to the operations of a fleet of pelagic fishery units. Its economic

practicability would depend upon the balance between the monetary value of such savings and the cost of the service. No New Zealand data can be provided with regard to this point. It may, however, be said that since we are at the stage when the exploitation of pelagic fish species is a matter of uncertainty, and exploratory fishing operations are a form of speculative enterprise that does not appeal to private individuals or commercial firms, there is a good case for such exploration being undertaken by the state. All these species appear to school in the summer season, and systematic aerial reconnaissance by R.N.Z.A.F. planes would appear to be the best method of survey and might be carried on in the course of service training. An actual case of useful data with regard to the occurrence of seals on the Bounty Islands (300 miles E.S.E. from Otago harbour) obtained on a recent navigational training flight may be mentioned. As observation of seal colonies from surface craft is notoriously difficult in the prevalently high seas of these southern latitudes, there is a suggestion that aerial surveys would supply a want in this connexion. Arising from consideration of the habits of the principal predatory enemy, the fisherman, it has also been suggested that aerial reconnaissance would be the most effective method of detecting fishing vessels poaching in prohibited areas, at least in the hours of daylight.

Shoals of fish do not necessarily appear at the surface and may remain in obscurity in the lower water strata. It has been shown that such shoals may be detected by the use of echo-sounding apparatus. The only vessels possibly available in New Zealand for such operations are those of the R.N.Z.N. The employment of naval units for making observations of value towards the better understanding of fishery phenomena in this and in other fields of marine biological and hydrological research is not without precedent.

From the point of view of those who are responsible for fish conservational measures—viz., the Government's official advisers on fishery administration—there is generally no disposition to regard in a favourable light the developments in the augmenting of fishing efficiency which are brought about by technical and mechanical improvements in the gear and methods used. There is too much evidence of the economic harm wrought by over-fishing. Fishermen and the commercial interests behind them are urged on towards the devising or adoption of methods calculated to catch more fish in shorter time owing to the pressure of competition. This may come from their own countrymen or from foreign competitors on the deep-sea fishing grounds of extra-territorial waters. On New Zealand fishing grounds there is fortunately no international competition. There is, however, competition between the exploiting agencies *inter se*, and this accelerates the race between exploitation and conservation which tends to induce in the minds of fishery administrators nostalgia for the days when fishing methods were more primitive. That is the position at the present time in New Zealand and the situation is not an easy one to deal with equitably and effectively.

Nevertheless, there is an important part to be played by scientific developments in relation to the productive aspect of the fishing industry. The problem is not so much to intensify fishing power as to rationalize and economize fishery operations—to eliminate as far as possible waste of

power, time and material. The first is almost entirely an engineering and mechanical problem. The second is partly so but it is also biological; and the last, the saving of material, if one includes, as one should, the avoidance of the waste of fish by the destruction of undersized individuals, is largely biological though it also introduces the question as to what can best be done by modification of the pattern of fishing gear to prevent or minimize, especially in the operation of trawl-nets, the destruction of small fish which are almost useless in the market but potential producers of further harvests by growth and reproduction if left in the sea. The biologist is thus laying the foundations for more rational and economical fishing by his study of growth-rate, size of fish at maturity and indeed by every sort of light that can be thrown upon the life history of marketable fishes. Fish population studies as a basis for fishing forecasts also have an important economic bearing.

One of the most impressive gaps in our present knowledge which has a bearing on fishing economics and fishery development in New Zealand is in respect of the migratory movements of pelagic fishes of which the sardine is the most important example. After a succession of years in which sardines were observed to shoal in substantial quantities on the western side of Cook Strait and in the Marlborough Sounds with annual and seasonal regularity, a regular fishery was established for the supplying of a cannery. After a promising start and two moderately successful seasons there has been a falling away in supplies and the canning firm is faced with serious difficulties. The problem is to ascertain the cause or causes of the absence of the fish from their former habitat—to elucidate the environmental factors which condition their occurrence. This would appear to call for a long term investigation of the hydrological conditions, since such movements of clupeid fishes have been shown elsewhere to be correlated with water temperature, and for contemporaneous research on plankton which may be an essential factor in relation to the fishes' feeding habits and also has its general and specific correlations with the physical and chemical qualities of the water. Intermittent phases of sardine abundance are also known to have occurred in other coastal waters where periods of apparent plenty have suggested ideas for the creation of a fishery, but action has been halted by the evidence as to the occurrence of seasons when the fish are apparently absent.

As mentioned in the report on oceanography, it is most probable that the basic causes of variation in the hydrological character of our coastal waters are to be sought in the major movements of ocean masses, though these may be complicated by the local action of tidal currents and winds. It is thus evident that the results of long-term hydrological surveys and plankton investigations are a necessary pre-condition to the elucidation of these fishery problems and the establishment of commercial fisheries on a sure economic foundation. The scientific, and economic, question is as to the best way of securing the required data. The answer to the scientific part of the question will be supplied by reference to the technical methods of British, European and American hydrologists whose labours at sea and in the laboratory over the last forty years have brought about progressive improvements in instruments and methods. So far as plankton data are concerned the systematic use of A. C. Hardy's continuous plankton recorder

would appear to be a very suitable method for adoption. The answer to the economic question must be in terms of money, ships and men. This is the aspect which presents most difficulty, more especially because, although it must be admitted that there still exists a good deal of obscurity about the occurrence of marketable fishes in the New Zealand seas, and thus about the absolute potential value of these natural resources to the state, one does know enough about our fish population, both from empirical experience and from first principles, to recognize that if our fishery research programme is to be drawn in proper perspective with our national fishery assets it will need to be of modest proportions. The quantitative limitation of our supplies is indicated by the fact that the greatest quantity of 'wet' fish landed in any one year was 363,128 cwt. for 1936–1937, valued at £360,466. For the same year the total value of all fishery products was £444,301. Of the total 'wet' fish (i.e. the ordinary commercial sea fish excluding molluscs, crustaceans, whitebait and salmon) 99 per cent consisted of the class known as demersal. There is every indication that this class has been and is being exploited to the full. The possibilities for further fishery developments lie in the as yet almost untried field of pelagic fishery, which is the reason for giving it priority in this discussion. However, with regard to the demersal fisheries, and to off-set the reference made above as to limitations upon research efforts, it may be appropriate to quote the concluding words of the first departmental fishery investigational report ever made in New Zealand: 'It is cheaper to investigate our resources in advance than to investigate their depletion after it has taken place.' *

Returning, in conclusion, to the problem of the national economics of fishery and ancillary oceanographical research, it would appear that the only practicable means of extending the work beyond the confines of very limited and local operation would be by enlisting the co-operation of naval units. There is reason to believe that marine research operations would be in no way obstructive to normal naval training but would in certain aspects be of assistance to such training. The examination of material collected, and the collation of recorded observations such as temperatures, would of course involve the employment of a civilian staff ashore. It is, however, the operation of a sea-going vessel that incurs the heaviest financial burden. The precedents for co-operation in scientific research already established in the British and other navies might well be followed and indeed expanded in the post-war period.

* Hefford, A. E., Report on the fisheries of the Hauraki Gulf; Report on Fisheries for the year ended 31 March 1929, Appendix I: Marine Department, N.Z. (1929).

OCEANOGRAPHY OF THE NEW ZEALAND SEAS

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INTRODUCTION

If New Zealand's field of oceanographical interests be taken to be congruent with its political boundaries which reach as far north as the mandated territory of Samoa and as far south as the coasts of the Ross Dependency, it will cover a vast expanse of ocean roughly 4,000 miles long from north to south and about 2,000 miles wide from east to west : an area bounded on the north by latitude 13° S. and on the south by latitude 80° S., on the west by longitude 160° E. and on the east by longitude 160° W. This comprises the eastern half of the Tasman Sea and an appreciable portion of the south-west Pacific Ocean.

From its geographical position, remote from the great centres of civilization, and from its small population whose economic interests are directly or indirectly concerned almost entirely with agricultural products, this Dominion's participation in oceanographical research up to the present time has been negligible at least so far as the open seas are concerned.

As an official adviser on fisheries administration, the present writer's interest in oceanographical phenomena turns mainly upon their importance as factors affecting our fish supplies. The correlations are not likely to be simple and so far very little detailed light has been thrown upon the relationship between our fish stocks and the physico-biological character of their habitat. It may however be taken as an established fact that the hydrological and marine biological conditions in the seas adjacent to these islands are very largely governed by the character and origin of the ocean masses of which they form part. It thus follows that the origins of our fishery-oceanographical relationships must be sought at ocean-wide distances from our own shores.

New Zealand is placed by its geographical position in the path of three distinct major movements of ocean water masses. Its northern extremity lies in the track of the westward moving South Equatorial Stream, part of which goes past the North Cape to impinge on the east coast of Australia to form the East Australian Current which eddies around the Tasman Sea and flows from south to north off the western coasts of both South and North Islands. Another part of the South Equatorial Stream is diverted southward and eastward off the east coast of North Island until, in the zone lying eastward of Cook Strait, it meets the stream which, originating

in the Antarctic Ocean, has washed the south-eastern and eastern coast of the South Island. There is thus to the eastward of Cook Strait and to a less extent off the south-west end of South Island an intermingling of waters which are respectively of tropical and antarctic origin. The hydrological character of these two water masses differs not only as to temperature but also as to salinity and concentration of other mineral salts. The related differences of flora and fauna must be of appreciable degree both qualitatively and quantitatively, but so far as observations by New Zealand workers are concerned no comprehensive data have yet been collected to elucidate such relationships.

The distribution of fish species, mainly those of commercial importance, and of inshore and littoral species of mollusca and crustacea, however, has become fairly well known, and will be further discussed later. For all oceanographical data relating to the open seas in the region above defined, we are indebted to the reports on expeditions made by ships from the Northern Hemisphere. In this paper, which is being prepared at short notice and without access to the more recent literature, one can only refer to the broad facts of the oceanography of the region as elucidated by these expeditions.

Physical oceanography

The earliest soundings in the coastal waters of New Zealand were made by Captain Cook's *Endeavour* in 1769. The depths shown in current Admiralty charts were obtained by H.M. Ships *Acheron* (1849–1851), *Pandora* (1853–1855) and *Penguin* (1904). Special local surveys for harbour navigation have subsequently been made. In June 1937 H.M. Admiralty Survey Ship *Endeavour* arrived in New Zealand and commenced the task of making a re-survey of the New Zealand coastline but her operations were discontinued on the outbreak of war in 1939. By the use of echo-sounding apparatus the collection of bottom contour data has been greatly accelerated and extended in the last 20 years. The *Bear of Oakland* ran contours from Tahiti to New Zealand, from New Zealand to Easter Island, from New Zealand to the Bay of Whales and took soundings in the Ross Sea, the results of which were embodied in a report by Roos in 1937. On her Pacific cruise in 1929 the *Dana* took soundings with hydrological and plankton observations at stations along the following lines: Auckland to East Cape and thence southward between the meridians of 178° and 179° E. longitude to latitude 47° S.; thence westward towards the Otago coast to 175° E. and thence in a northerly direction to Cook Strait; thence northerly past Cape Egmont to Cape Maria van Diemen and thence across the Tasman Sea to Newcastle, N.S.W. *Discovery II*, in her voyages between 1929 and 1939 has worked lines of stations on six different courses to the Ross Sea sector of the Southern Ocean and has circumnavigated these islands besides making one run off the East Coast of North Island from Auckland to Wellington on which dredge samples were taken in addition to the routine hydrological and plankton observations. The information obtained from these expeditions is of considerable interest and has thrown important light on the universal obscurity that previously prevailed, but there are many voids remaining to be filled. Dr T. Wayland Vaughan's statement that 'the South Pacific

is the least known of the great oceanic areas,' made as recently as 1938, still stands as a challenge.

The general character of the sea bottom contours in the New Zealand region may be pictured as dominated by the following broad features: to the south-west is the Tasman Basin between New Zealand and Australia, with maximum depths exceeding 5,000 metres; to the south-east is the deep area formed by the South Pacific Basin containing depths of over 6,000 metres and connecting with the Tasman Basin by a trough to the westward. To the north-west of this basin is the platform on which the islands forming New Zealand stand; this has an eastern extension from the extremity of which rise the Chatham Islands group situated 300 miles to the eastward from the South Island. On the northern side of this relatively shallow area is a trough coinciding with the deep channel of Cook Strait.

Depth data for the vicinity of the New Zealand coasts are receiving progressive additions from the work of such units as the government steamship *Matai*, the lighthouse service steamer operated by the Marine Department, by the submarine cable ships and other craft. An interesting case of an addition to our knowledge of the bottom contours is that of the discovery of the 'Mernoo Bank' which was fortuitously made by S.S. *Mernoo* when, approaching the New Zealand coast in thick weather and therefore taking precautionary soundings, she came upon one of 32 fathoms (59 metres). According to the existing Admiralty chart this indicated close and even dangerous proximity to land. The Captain therefore ordered the anchor to be dropped and waited for daylight, but when this came it was evident that no land was in sight. Thus they came upon a previously unknown shoal surrounded by depths exceeding 200 fathoms. The locality was subsequently surveyed by S.S. *Matai* and, although the bank (situated between 43° 10′ and 43° 35′ S. and on both sides of longitude 176° E.) could not be completely demarcated, it was found to cover an area of about 400 square sea-miles shoaling at one place to 21 fathoms. The discovery of most promising practical interest was that the bank apparently carried a good stock of commercially valuable fishes—a virgin fishing ground at a distance of 90 miles from the east coast of South Island. Uncharted pinnacles rising from the depths of Cook Strait have also been located by fishermen. The circum-island platform on which New Zealand stands, with the exception of the already mentioned eastern extension to the Chatham Islands, is relatively narrow and at no point is the distance from the coast to the 100 fathom line very considerable. This has a limiting effect on the area of offshore fishing-ground available.

HYDROLOGY

Dynamical

The mass movements of the ocean waters surrounding New Zealand have already been indicated so far as surface streams or currents are concerned. Coastal currents are influenced to a varying extent by the effects of tidal streams and winds and abnormal variations have occasionally involved difficulties and disasters to navigators. They also have a bearing on biological conditions. Some of the most obvious, or most appreciated,

examples of this are the effects on fish propagation to which further reference may be made later. So far as they are of interest to navigators the nature of surface movements is described in the 'Admiralty Pilots' relating to the several portions of the region. The elucidation of the more fundamental aspects of ocean dynamics has come from the observations made on the aspects of ocean dynamics has come from the observations made on the research vessels *Dana* and *Discovery II* on their cruises in the New Zealand region to which reference has been made. Stations were 'worked' at intervals along their courses on a systematic plan. Data as to depth and as to temperature, salinity, phosphate concentration and pH of the water at selected depths have thus been obtained by the staff of *Discovery II* for all 'stations,' with determinations of oxygen and nitrate at less numerous points. In her later voyages silica and nitrate content of water samples were also determined. Similar examinations were made by the *Dana's* scientists. From such data it has been possible to determine the direction of currents in different horizontal strata. These are well indicated by sectional diagrams of isotherms and isohalines given in the hydrological reports of the Discovery Committee. It is from this work that all our knowledge of the character and movement of the ocean water masses which occur in this region have been obtained. The main features have been described in the Reports of the Discovery Committee, and such data have also been embodied in Schott's general account of the hydrology of the Pacific Ocean. The outstanding facts elucidated by the work of *Discovery II* relate to the character and movement of Antarctic water. More detailed information has been gathered in respect of the South Atlantic section, the South Pacific section of the Southern Ocean having so far provided a less complete picture. The bottom contours of the oceans are considered to have a profound effect on water movement but there are large gaps in our knowledge of the relief of the bed of the South Pacific. It is clear, however, that the water circulation in southern latitudes has the same general character in all three ocean sectors, in all parts of the southern ocean. Three distinct depth strata have been shown to occur: a cold surface current of low salinity moving northward and eastward, a cold saline north going current moving along the bottom, and a warm intermediate layer of higher salinity forming a current which moves in a southerly direction. As more northerly latitudes are reached the depth relationships between these layers undergo changes and the phenomena of sinking and upwelling, the locations of which are designated as 'convergences' by the hydrologists of *Discovery II*, have been noted as conspicuous features in the Southern Ocean. Such convergences are demonstrated as lines of abrupt change in hydrological conditions and have been shown to act as effective barriers to the distribution of many plankton organisms. They are formed where cold surface water of low salinity flowing northward and eastward from the antarctic meets warmer and more saline water of tropical origin from the north. An antarctic convergence and a sub-antarctic convergence have been roughly demarcated as a result of the work of *Discovery II*. It is evident that their location will be subject to seasonal and annual variation and that the seas off the coasts of New Zealand will be influenced as to both physical and biological factors by these oceanic phenomena.

It is noteworthy that New Zealand lies in the zone, or within the contours, of maximal seasonal variation in the temperature of surface water for the South Pacific, which is 6° C. The 5° contour approaches close to the southern half of the South Island and the 4° contour is not far distant on the eastern side but is remote from the West Coast.

A general idea of *surface temperature* conditions and of their normal seasonal variations is obtained by considering isotherm contours. For the month of maximal warmth (February), New Zealand lies between the isotherms of 20° C. to the north and 15° C. to the south, with an appreciable degree of southward shift for the Tasman Sea waters. The 10° C. isotherm passes through the Auckland Islands.

In August, the month of minimal surface temperatures, the 15° C. isotherm passes to the northward of North Cape and the 10° C. isotherm touches the middle of the east coast of South Island, with a southward displacement on the West Coast. The 5° C. isotherm passes in proximity to the Auckland Islands.

SURFACE SALINITIES

The general trend of surface salinities for winter is shown as follows :

35·0‰–35·5‰	off east coast of North Island.
34·5‰–35·0‰	eastward of Cook Strait and of East Coast of South Island down to Banks Peninsula ; off whole West Coast from North Cape to the southerly extremity of South Island.
34·0‰–34·5‰	off east coast from Banks Peninsula southward to Auckland and Campbell Islands and south of south-west extremity of South Island.

The above indicates the broad aspect of the sea-surface conditions as they affect the coastal waters of New Zealand. The degree of variation to which they are liable is shown by records of the occurrence of ice which had drifted from the Antarctic as far north as the Chatham Islands, abreast of Canterbury, in the years 1855, 1883 and 1892. Such variations must have an important bearing on the distribution of plankton organisms and the associated phenomena of whale migration and the distribution of fishes. The possibility of forecasting these conditions by long period studies of the hydrological conditions in the Southern Ocean is thus a question of more than academic interest.

Up to the present the contributions of New Zealand workers to hydrological data have been made in very limited fields, and for the most part remain unpublished. Surface temperature records from the logs of certain ships are available and some of them have been collated, e.g., from some of H.M.N.Z. naval vessels and the government steamer *Matai*—for the purpose of obtaining monthly means, but the readings were too irregularly distributed in space and time to give very significant results. In connexion with the study of the natural history of commercially important fishes and

molluscs, the marine biologist on the staff of the Marine Department has from time to time recorded water temperatures and taken water samples for estimations of salinity and other solutes in the inshore waters. A brief report by A. M. Rapson on 'Chemical Hydrology of N.Z. Waters,' giving some results and conclusions from his investigations in sardine and toheroa habitats, is attached as an appendix hereto. As there is no hydrological specialist in New Zealand, these analyses have been made in the laboratories of the government analyst. For several years inspectors of fisheries have recorded surface temperatures in the vicinity of the northern rock-oyster beds. From these it is evident that the surface temperatures in shallow bays and harbours are largely influenced by atmospheric conditions.

The following examples are typical of rock oyster habitats :

MEAN MONTHLY SURFACE TEMPERATURES FOR THE TEN YEARS, 1929 TO 1939

	Bay of Islands off Russell (East Coast) °C.	Kaipara Harbour Whakapirau Estuary (West Coast) °C.
January	20·5	20·4
February	20·5	22·0
March	20·1	21·0
April	19·0	19·1
May	16·2	15·0
June	14·1	12·6
July	13·3	11·6
August	13·2	12·2
September	14·0	13·8
October	15·8	16·3
November	16·3	18·0
December	19·1	21·6

Daily readings of surface temperatures in Otago Harbour have been recorded by the Curator of the Marine Station at Portobello.

In connexion with the so-called 'Cape Expeditions' (observation and communication parties stationed on the normally uninhabited Auckland Islands (166° 12′ E., 50° 32′ S.) and Campbell Islands (169° 8′ E., 52° 33′ S.) as a wartime precaution) a programme of scientific work, mainly biological, was organized under the direction of Dr Falla of the Canterbury Museum. Among its fruits are daily records of surface temperatures from 1941 to 1944 for the Auckland Islands and from 1941 to 1946 for the Campbell Islands. In 1944 continuous tidal observations throughout a lunar month were made at Auckland Island.

BIOLOGICAL

Information on our marine fauna and flora has been collected over the last hundred years or more by the work of many persons. A bibliographical

list would include the following names : Forster, Gray, Quoy et Gaimard, Richardson, Gunther and Regan, who described and classified collections brought back from successive exploratory expeditions including those of the *Endeavour* (1769–1779), *Astrolabe* (1835), *Erebus* and *Terror* (1840), *Challenger* (1872–1876) and *Terra Nova* (1910–1911). Prominent among New Zealand names would be Hector, Hutton, Clarke, Waite, Griffin and Phillipps and Chilton (crustacea) ; Kirk, Suter, Cheseman, Benham, Finlay and Powell (mollusca) ; J. A. Thomson and Percival (brachiopods). Most of their papers have been published in Transactions of the New Zealand Institute (Royal Society of N.Z. since 1934).

Marine algology owes most to the assiduous labours of Laing, with additions in recent years by Moore and Cresswell.

Substantial additions to knowledge of littoral and sub-littoral species were made by Mortensen's Pacific Expedition, 1914–1916, in which extensive collections were made in the vicinity of the coasts of New Zealand and of the Auckland and Campbell Islands, the various groups of which have been the subject of papers written by Professor Mortensen himself and by numerous specialists over the subsequent years. The most interesting general result of this expedition would appear to be the evidence for connecting the marine fauna of these so-called sub-antarctic island areas with the biological regions of New Zealand and Australia rather than with the littoral and sub-littoral faunas in the same latitudes to the eastward.

An outstanding effort by New Zealand naturalists was the expedition to the Auckland and Campbell islands in 1907 under the auspices of the New Zealand Institute, the marine biological results of which were reported on by Waite (fishes), Suter (Mollusca), Chilton (Crustacea), Benham (Annelida), Dendy (Holothuria), H. B. Kirk (hydroids) and Chapman (Foraminifera).

Young (1929) has described the marine fauna of the Chatham Islands.

Ecological surveys have received little attention up to the present, and much remains to be done in this field. Oliver (1923) has made local studies of littoral plant and animal communities. (Powell (1937) has made a faunistic survey of the benthos of Auckland and Manukau harbours).

The check placed by the recent war upon all research activities, except those directly connected with the production of munitions or food supplies, has been attended by one noteworthy exception in the case of the 'Cape' expeditions mentioned above in connexion with hydrology. Besides affording the opportunity for making daily observations of surface temperatures in the vicinity of our southern islands, the whole year's sojourn enabled one young science graduate who was stationed on Auckland Island, with the assistance of other members of the party, to make observations and collections over a twelvemonth period of the land and fresh-water flora and fauna, but more particularly of the marine organisms. Shore collecting and dredging were carried on and plankton collections were made by a series of tow-nettings. The bulk of the collected material has yet to be examined. In a general interim report it is stated that the vertebrates that appeared to occur in greatest abundance were birds and pinnipedia. Marine fishes appeared to be scarce, *Nothothenia* sp. (all specimens of which were found when examined to be infested by nematode parasites encysted in the muscle tissue), *Tripterygium* sp. and a small pilchard-

like fish were the only species obtained. Very interesting evidence on the specific feeding habits of birds and seals was obtained, and the relative scarcity of fish in the stomachs of birds—with the exception of two species of terns that fed almost exclusively on the small clupeids, and the Auckland Island shag and mutton-birds whose stomachs were found to contain a few of these fish among other food—reflects and corroborates the paucity recorded by the observers. Squid is stated to be the most important food organism in the area for marine vertebrates, providing almost the entire dietary of the albatrosses, mollymauks, cape-hens, white-headed petrels and part of the food of mutton birds. Squids are also eaten by sea-leopards (*Hydruga leptonyx*) and for the greater part of the year form the principal food of the hair-seals (*Otaria hookeri*). The most important food-organisms for vertebrates including fishes in the Auckland Island waters are stated to be squid (species unnamed), 'lobster krill' (*Munida subrugosa*), prawn-like decapods, amphipods and mysids, and small clupeids. Tow-nettings show that the smaller planktonic animals become fewer in numbers in autumn, are scarce in winter, and increase rapidly after the diatom outburst in spring. Littoral animal associations were studied and endoparasitic organisms (nematodes, trematodes, cestodes and Acanthocephala) from birds, seals and fishes were collected.

Mr Dawbin's own collections—excluding those that were made by other persons—contained the following phyla, orders and classes. (The figures in parentheses represent the number of marine samples collected in which the group occurred):

Porifera (9).
Coelenterata. Hydrozoa (5), Scyphozoa (6), Actinozoa (6), Ctenophora (2).
Platyhelminthes. Turbellaria—marine only (6), Trematoda (2), Cestoda (17), Acanthocephala (19).
Nematoda. Parasitic (38), free-living (2).
Nemertea (11).
Polychaeta (28), *Sipunculoidea* (4).
Crustacea. Copepoda (45), Cirripedia (9), Leptostraca (1), Mysidacea (numerous observations), Cumacea—first record (1).
Tanaidaceae (2). Isopoda (19), Amphipoda—including developmental stages of Phronima (35), Decapoda—crabs, prawns and 'lobster krill' (27).
Arachnida. Pycnogonida (6).
Mollusca. Amphineura (specimens of several species), Gastropoda (numerous), Nudibranchiata (8), Lamellibranchiata (33), Cephalopoda (7).
Polyzoa (2).
Chaetognatha (3).
Echinodermata. Asteroidea—including developmental stages of *Calvasterias laevigata* (36), Ophiuroidea (14), Echinoidea (9), Holothuroidea (10).
Chordata. Enteropneusta (1).
Tunicata. Ascidiaceae (10), Thaliaceae (1).
Pisces, including fresh water galaxiids (8).

The above catalogue-like statement has been given to indicate the amount of recent marine biological data and material that are available to amplify the results of Mortensen's investigations. It will also show that the Dominion has young potential marine biologists capable of doing good work when the opportunity offers. Records of considerable interest were also made from observations on the distribution and habits of the birds and seals of these southern islands in which various members of the island parties collaborated with Dr Falla who is preparing reports on these classes.

On account of their commercial importance the marine fishes of New Zealand have been the object of the most substantial and continuously sustained collecting efforts, and they thus constitute the class of which the life histories and distribution are most fully, though by no means completely, known. As might be expected from the geographical position of New Zealand in relation to the peripheral hydrological features to which reference has been made, there is considerable variety in our marine fish fauna. It has tropical and sub-tropical forms such as the larger sharks (*Cephaloscyllium*, *Sphyrna*, *Alopias*, *Cetorhinus*, *Carcharodon*, *Galeocerda*), the marlins (*Makaira*) with an occasional swordfish (*Xiphias*), flying-fish (*Evolantia*, *Cypselurus*), and sun-fish (*Mola*), besides species common to eastern Australian waters such as snapper (*Pagrosomus auratus*), Kahawai (*Arripis trutta*), garfish (*Hemirhamphus intermedius*) and certain dogish and ray species ; and quite distinct from these are characteristically sub-antarctic fishes including the ling (*Genypterus blacodes*), hake (*Merlucius gayi*), elephant-fish (*Callorhynchus millii*), apparently identical with species that occur in abundance off the coast of Chile. Similar relationships appear to be shown in respect of Mollusca, Crustacea and other invertebrates.

Up to the time of the trawling investigations made by the S.T. *Nora Niven*, chartered by the N.Z. Government, in 1907–1908, with a view to assisting and stimulating commercial fishing, ichthyologists had depended for their material on casually collected individual specimens. The *Nora Niven's* collections of fishes were examined and described by Waite, Mollusca by Suter, Annelida, etc., by Benham, Crustacea by Chilton and Algae by Laing. Waite's reports represent the most complete and comprehensive monograph on New Zealand ichthyology yet published, adding considerably to the earlier work of Hector and Hutton. No comprehensive work on New Zealand fishes has since been published. A useful Bibliography was compiled by W. J. Phillipps of the Dominion Museum and published by the Marine Department as *Fisheries Bulletin No. 1* in 1927. Suter's *Manual of the Mollusca of New Zealand* is still the most comprehensive and authoritative work on this class but requires up to date revision. Powell's *Handbook* contains an augmented list of species with revised nomenclature together with a popular account of some of the more important families. No comprehensive monograph on Crustacea has yet been written to succeed Miers' *Catalogue of N.Z. Crustacea* (1876).

Information regarding the fishes, molluscs and Crustacea of economic importance is given in the Annual Reports of the Fisheries Branch of the Marine Department of which the statistical statements throw light on the relative abundance and distribution of the various species. As appendices to these departmental publications are the annual reports of the Chairman

of the Board of the Portobello Marine Fish-Hatchery and Biological Station describing the nature of the work carried out and the observations made on the marine fauna of Otago Harbour.

EXISTING AGENCIES FOR MARINE BIOLOGICAL RESEARCH

The work done by New Zealanders, to which brief reference has been made, has been largely carried out under the auspices of the following institutions : the Dominion Museum at Wellington, the Provincial Museums at Auckland, Christchurch and Dunedin, and the Biological Departments of the four University Colleges. The staffs of all these institutions have always been handicapped in their research work by pressure of other duties and by very limited funds. The Royal Society of New Zealand, formerly the New Zealand Institute, from time to time makes small sums available as grants-in-aid to individual research workers.

The only institution in the Dominion which could be described as concerned entirely with marine biological research is the 'Portobello Marine Fish Hatchery and Biological Station' situated on the shore of Otago Harbour a few miles for the City of Dunedin. Unfortunately this station was established, as one might almost say, under false pretences. Its construction was financed by a government grant, made through the Marine Department (under a Section of the Fisheries Act which provided for the establishment of fish hatcheries) together with smaller contributions from Acclimatization Societies and the Dunedin branch of the New Zealand Institute, on the grounds that by means of such a station it would be possible to acclimatize valuable commercial fishes from the Northern Hemisphere and to augment our indigenous food fishes by methods of artificial propagation. That was at the beginning of this century when the facts of marine ecology had been little elucidated, and New Zealanders were not alone in failing to realize the impracticability of increasing the fish stocks of the open sea by artificial hatchery operations ; nor did those enterprising and wishful thinking pioneers recognize that an Atlantic species, whose propagation rate is normally exiguous on account of the high degree of mortality sustained by its pelagic embryonic and larval stages, and that is subject to a fine degree of correlation between spawning and hydrological factors in its environment, would stand a very remote chance of establishing itself in New Zealand seas. The present-day commonplace facts of marine ecology were still unknown. At the modest cost of £1,500 the station, comprising an aquarium, small laboratory, artificial ponds and curator's cottage, was completed in 1904. During the next 10 years 100 lobsters, 195 young turbots and 16 crabs were successfully shipped from England and established in the sea-water ponds at Portobello as a breeding stock. An attempt to bring out herring ova failed. It was demonstrated that turbot and lobsters could be kept and fed in captivity. Some of the lobsters grew to maturity and spawned, but as we should expect with our present-day knowledge, nothing came of the liberations of their young progeny or of the adult turbots in the open sea. There was nothing lacking in the zeal or the resourcefulness and assiduity of the staff and the board of management in their attempts to achieve the

impossible. Meanwhile under the inspiration and with the active collaboration of the Chairman of the Board, the Hon. G. M. Thomson, and Dr Benham, Professor of Biology in the University of Otago, good progress was made in biological work. This was mainly in faunistic studies and in the investigation of the life history and reproduction of the food fishes on the lines that had been followed by Mackintosh at St Andrews and Cunningham at Plymouth. The results were published in G. M. Thomson's *History of the Portobello Station* and in papers in Transactions of the N.Z. Institute. The small aquarium, thanks to its excellent water supply from Otago Harbour (which may be more aptly described as a fiord, sound or loch), was and still is a very successful feature of the station. Its usefulness to the public is limited by its distance from the city, involving a journey of about half an hour by railway and a crossing of the harbour by boat from Port Chalmers. The modestly equipped laboratory has been continuously available for marine biological workers and has been utilized by zoologists from the University Colleges of Dunedin and Christchurch, but there has never been sufficient financial provision for an adequate permanent staff working under professionally qualified scientific direction. The institution was only barely saved from extinction during the financial depression in the early 'thirties up to which time it had operated with an annual government grant of £700. The grant was then reduced to £300 per annum—a bare maintenance allowance which reduced research possibilities to a minimum. Meanwhile a project (from an unofficial source, be it said) for establishing an aquarium and biological station at Wellington had been submitted to government at the time when plans for the Centennial Exhibition of 1939 were being considered. Nothing has yet come of this proposal. The Minister of Marine (now Prime Minister) promised that the Portobello Station would be 'kept going' until some similar but more centrally situated institution was established. During the war years the state of almost suspended animation has been inevitably prolonged. At the time of writing it may be said that a state of crisis has been reached. The adverse factors in the situation are that the working plant is old and in a condition of disrepair which calls for early renovation, that the experienced and conscientiously competent curator (Mr W. Adams) has just retired, and the Secretary-Treasurer of the Board (Mr G. Howes), who had managed its business affairs and supervised the station activities through many difficult years, has quite recently and suddenly died. On the other hand, the need for increased utilization of the actual and potential resources of this station appears in two new and important aspects. One is that current work by the Department of Physiology of the Otago University Medical School in research on nerve physiology needs live squids as an essential material; such work could only be done at Portobello. In the second place, the new curriculum for science teaching in the secondary schools of the Dominion gives an important place to the teaching of biology. This will not only call for the provision of material that can best be supplied from a marine biological station, but will also create a greater need for an institution where teachers in training may receive instruction in the technique of biological work. The Portobello Station has in the past served this purpose to a limited extent in that it has enabled professors and students from the two South Island University Colleges to pursue vacation courses there.

Thus there is an evident need and a demand for the resuscitation of this institution to such full functional activity as has never hitherto been experienced. Working personnel would be available if the necessary material and financial provision were made.

In earlier years claims were made for government support for the Portobello Station on the grounds that it could serve a useful if not an essentially necessary purpose as a fishery investigation station. This was only true in a limited and local sense and at the time when the Marine Department had made no provision for the scientific investigation of any fishery problem. In the year 1927 the Fisheries Branch of the Department had acquired the services of a marine biologist in the person of Mr M. W. Young who had been marine biologist at Portobello and who remained stationed there for a time before transfer to departmental headquarters at Wellington. The time had arrived when it had to be recognized that a basis of biological fact was essential for the proper understanding of the problems of fishery administration. The field for the necessary investigation was not in Otago Harbour, however, but in the several areas where the fishing operations were carried on. The most urgent problems were in the Auckland province in connexion with the Hauraki Gulf snapper and flounder fisheries. In the same province were the rock oyster beds and the principal Toheroa (*Mesodesma ventricosa*) habitats which, next to the Foveaux Strait dredge oyster grounds (on which Mr Young had carried out preliminary investigations before his transfer to Wellington), were the sources of our most valuable marketable molluscs. In 1929, by the courtesy of the late Professor Johs. Schmidt, Mr Young was enabled to make a passage on the *Dana* across the Tasman Sea to Australia which afforded an opportunity for seeing the operations of a modern research vessel and also for studying the rock oyster fisheries of New South Wales.

In 1936 Mr Young was succeeded as Marine Biologist by Mr A. M. Rapson who has since carried out departmental investigations mainly in connexion with the distribution and life history of the Toheroa and of the more important or more accessible commercial fishes. Statements on the nature and progress of these investigations are given in the departmental Annual Reports on Fisheries. At the invitation of the 'Discovery' Committee Mr Rapson was enabled in the period January to June 1938 to make a voyage in *Discovery II* to antarctic waters and thus to obtain a practical training in the biological and hydrological work at sea that is of fundamental importance for fishery investigation as for whaling research.

It is well understood by every experienced investigator of fisheries that, although a complete understanding of ecological factors is ideally desirable, the questions of most urgent and immediate importance are connected with the catching of fish—with the effects of fishing operations on the fish population. Failing the possession of a research vessel equipped with suitable fishing gear the investigator must do the best he can as a guest aboard a commercial fishing boat. This has been the usual practice for many of our departmental observations. There are, however, definite limits to what can be done when the operational initiative is not with the investigator. More especially in connexion with Danish seining investigations and also for other experimental fishery operations and for a survey of oyster grounds in Foveaux Strait, the Department has periodically

chartered a commercial fishing vessel. Such arrangments provide only partial and temporary service. To keep pace with the problems, especially those involved in the task of overtaking, and if possible forestalling, exploitational enterprise and energy with effective conservational measures and guiding fishery developments along rational lines, requires the full-time employment of a fishery research vessel. In spite of her short history as a Europeanized nation New Zealand is in no better position than the majority of other nations in the tortoise *v.* hare sort of race between conservation which tends to limp and the exploitation which progressively tends to accelerate. Our main difficulty has been the prevalence of the idea, encouraged in the past by those whose opinions were regarded as authoritative, that our fisheries resources were well-nigh as limitless as the seas themselves ; that they were merely being scratched ; that only greater fishing enterprise and energy were necessary to win substantial wealth in providing food for the people and more commodities for export. It has been the task of twenty years to correct that notion and to obtain public and political understanding of the departmental view that New Zealand's fisheries are coastal and mainly inshore ; that the stocks are depletable by continuous fishing operations on what would be regarded as a very modest scale in the fishing regions of the Northern Hemisphere.

It is now some years since government approval for the provision of a fishery investigation vessel was given. The 65-foot diesel-engined vessel *Ikatere* was launched a few days before the outbreak of war and went immediately into service as a very useful naval auxiliary. She is now back and is being fitted out for fishery experimental and investigational work. She calls for notice in this report because she is a material factor of considerable potential importance in relation to the progress of marine biological work in New Zealand waters in the immediate future.

MARINE RESEARCH FOR THE POST-WAR YEARS

There is no difficulty in formulating a programme for future work. There are gaps to be filled and threads to be picked up in every portion of a vast field, and some portions that are still virtually *terra incognita.* The problem is to prune down the programme to dimensions that are not too ambitious to be proportionate to this small country's resources and to its other scientific commitments and needs. Proposals that are, so to speak, too academically fundamental, are likely to meet with little recognition on the part of the public and the people's representatives in Parliament ; and these are the keys to the public purse which must provide the wherewithal for the operation of every item in the programme.

It therefore follows that the proposals that are most likely to be carried into effect are such as can be connected with economic needs, such as fisheries, and practical interests of social significance such as education. The writer would not, however, have it inferred that he himself does not appreciate the value of every sort of biological fact on which light may be thrown by the individual worker from university or museum. The educational needs of the rising generation demand that such institutions should receive increased recognition and support, and it is considered that

they can play their part in a scheme that is primarily based on a ' practical ' or ' applied ' research policy.

If one regards New Zealand's interests as covering the 4,000 by 2,000 mile area mentioned at the beginning of this memorandum, one must divide this into (1) an inner (littoral and sub-littoral New Zealand) circle and (2) an outer (oceanic) circle in considering the geographical field of operations.

(1) is necessarily the field for Dominion national operations ;
(2) is necessarily a field that can only be tackled by extra-Dominion—i.e. by international or at least inter-British Empire collaboration.

In regarding the whole question from the point of view of fisheries problems it follows from what has gone before that the elucidation of the more immediate and urgent practical problems must be sought in area (1). The long term investigations likely to throw the ultimate light on our ' inner circle ' conditions must range into the ' outer circle ' of field (2).

(1) A Dominion programme

(*a*) *Problems.* There is unfinished work in every category touched upon in the historical account of the work of New Zealand contributors. All should therefore receive attention. The fishery aspect comes first, and its problems actually have some relationship to every kind of marine biological work from fish bionomics to invertebrate taxonomy, and certainly cannot be understood without reference to hydrology. The programme to be followed would therefore contain the following broadly defined items :

(i) Systematic experimental fishing to ascertain the distribution of commercially important species with regard to age-groups and maturity.
(ii) The location of spawning grounds and their correlation with hydrological phenomena.
(iii) Study of fish migration (by marking experiments and otherwise) and its correlation with hydrological phenomena.
(iv) Systematic plankton studies and hydrological correlations.
(v) Investigation of the biology (especially the distribution, food, rate of growth, and reproduction) of molluscs and Crustacea of economic importance.
(vi) Hydrology of territorial and near-territorial waters. (For the Tasman Sea collaboration with Australia is indicated).

(*b*) *Ways and means.* It is obvious that the above programme (from which ancillary details are omitted) will involve in the first place a sea-going vessel suitably equipped and a laboratory ashore for the working up of material. These are now available or about to be available. The Portobello Station might be a subsidiary to the main fisheries laboratory.

(*c*) *Personnel.* The single marine biologist now on the staff of the Marine Department could not cope with more than a fraction of the programme above adumbrated. Increase of staff will be necessary and this might involve accommodation problems. The marine biologist attached to the Portobello Station—if and when this desirable development takes place—could periodically take a share in the work at sea. The appointment of a hydrologist is indicated.

(*d*) *Administration and working organization.* The existing departmental organization could operate without change other than that involved by increased staff and financial requirements. Fishery research should not be separate from, but should be kept in close contact with, the department responsible for fishery administration. There is much to be said, however, for the setting up of an advisory or perhaps ultimately an executive committee or board, with representation from the administrative department, the commercial interests and from non-departmental and departmental scientists, who would consider and recommend programmes and perhaps provide the means for enlisting the services of unattached collaborators. For instance a fishery research vessel acquires considerable amounts of material of no interest, or of ephemeral interest, to its own staff. An organized scheme for the distribution of such material to academic workers, to various 'group' specialists, or even for teaching purposes would assist that class of biologists who have been the pioneers of progress in the past and would increase the volume of output of results in terms of pure science and quite possibly add to their value in the 'applied' sense.

This section may be concluded with the suggestion that the Portobello Station needs substantially increased support as an auxiliary to fishery research as well as an institution for pure research, for the supply of biological teaching material and other educational purposes. There should also be a closer—more organic in the administrative sense—connexion with the University of Otago. This has financial implications. Everything has financial implications!

This statement, which has run on too long, and yet contains many faults of omission, must be concluded with a brief reference to the 'outer circle.'

(2) An oceanic programme of international collaboration

It must suffice here merely to make reference to the suggestion made a few years ago by the 'Discovery' Committee. The reasons for supporting the suggestion for collaboration between the Mother Country, Australia, South Africa and New Zealand in continuing and completing the magnificent work of *Discovery II* in the Southern Ocean are implicit in what has been written above. In reality there is much the same reason for it as there was for rallying together in the prosecution of the war. Beginning with the British Nations it might, and should, develop into a United Nations Organization for Oceanographical Research. Before concluding, one final point, brought to mind by the thought that the R.R.S. *Discovery II*

sailed under a naval commission ; if one must maintain a navy in times of peace, would it not help to justify their existence and be an economic utilization of ships and men if more of them were turned on to oceanographical and fishery investigational work ? Speaking of, and to, though unfortunately not for, the Dominion of New Zealand, there is a tendency to regard a deep-sea research vessel as something beyond our means. If that is indeed the case, the need for financial economy alone should emphasize the necessity of utilizing naval units if such a course is practicable.

FISHERIES RESEARCH

By Rai Bahadur Dr S. L. Hora, F.R.S.E., F.A.S.B.
(Director of Fisheries, Bengal)

INTRODUCTION

In the programme of fisheries research of the Ministry of Agriculture and Fisheries and of the Scottish Home Department as is natural, attention is mainly devoted to the improvement of marine fisheries. As regards inland fisheries, there are only a few problems that are mentioned, such as the farming of estuarine fish and study into the migration, growth and habits of salmon and sea-trout. In some of the countries of the British Commonwealth, inland fisheries should receive much more attention and even for the development of marine fisheries scientific research should be on very different lines than that contemplated for the United Kingdom. My suggestions, therefore, are :

1. In the Indian seas, the European methods of fishing, particularly trawling, have not been successful, whereas the Japanese methods have proved far more superior in the Indo-Australian Archipelago and in the Bay of Bengal. There is thus great need to study the science and practices of Japanese methods of marine fisheries and follow up the lines of research which gave Japan a superiority in developing the fisheries of the Indo-Pacific tropical waters. The present is the most opportune time to gather information about Japanese methods.
2. In a number of countries of the British Commonwealth, fisheries research will be undertaken now for the first time. It is, therefore, necessary to bear in mind that ' the capacity for first class original research is rare and it is always difficult to find good men for senior research appointments. The development of research, therefore, should be sure but steady and a certain degree of " gradualness " in the extension of research institutes is to be advocated.' (Famine Inquiry Commission, Final Report, p. 198, 145.)
3. Every country has its individuality and, therefore, fisheries research should be wedded to its needs and requirements and, so far as possible, the aim should be to study the science and applicability of the existing methods with a view to effecting improvements in the light of the experience in other countries. Implantation of exotic methods, however efficient they may have proved to be in other countries, without the background of local knowledge is likely to result in a set-back to the development of the industry, as it happened in the case of Bengal and other provinces of India. It must be clearly understood by fishery scientists that technical knowledge is no substitute for local experience.

4. Arrangements are being made for imparting training in fisheries research in the United Kingdom to fishery personnel from the colonies. Unless care is taken to select persons with local experiences of fishery problems, trainees will go back to their respective countries with ideas of development not applicable to local conditions and thus the entire object of training will be frustrated.

PROBLEMS OF INLAND FISHERIES RESEARCH

There is a proposal to set up a Fisheries Research Institute in India, and there is no doubt that the problems of marine fisheries research will be found to be akin to those that are receiving attention in the United Kingdom, except that details will have to be adjusted to meet local needs and requirements. The writer proposed the following set up for the Inland Station of the Institute, and this is now submitted for comments, suggestions and criticism. Any deletions or additions in the programme will be most welcome.

It is proposed that the work of the Inland Station of the Institute should be organized under the following five sections with the allocations as indicated under each.

1. General section

Training, collation of fishery literature, library, publication, museum and statistics.

Training. I attach the greatest importance to training which we have now organized on a proper basis. Besides the six months' and three weeks' courses, there is a great demand for six weeks' to three months' training and for a week's training for the landlord class. This item of the programme should be implemented almost immediately.

Literature. An annotated bibliography of Indian fishery literature is another urgent necessity. The preparation of such a bibliography will stimulate research all over India, especially in the universities, and will give a clear picture of our research problems, province by province.

Library. The importance of having a good library in a research institute needs no emphasis. As it will be difficult to duplicate the Zoological Survey Library, it is highly desirable that the Zoological Survey of India should be brought back to Calcutta as early as possible. If the Zoological Survey of India is to be housed in a new building outside the museum, it is suggested that it should also be located in the proximity of the Indian Fisheries Research Institute. Such collaboration is not only needed for the sake of facilities for consulting literature but also for the sake of reference to zoological collections. In any case, considerable overlapping of zoological research will thus be avoided to the mutual benefit of both the institutions.

Publication. A research institute must have a journal of its own for the publication of the results of research, and I would, therefore, suggest that from its very inception, sanction should be accorded for issuing a Journal of the Indian Fisheries Research Institute. The publication of such a quarterly periodical will also stimulate research all over India.

Museum. Some sort of museum will have to be organized as soon as the buildings are ready, for a considerable amount of valuable material will begin to accumulate from different parts of India for comparative studies. We shall have to keep models of fishing craft and tackle and samples of the important elements of the fish biota affecting fisheries of different types. In fact, it may ultimately prove necessary to have a big fishery museum alongside the institute for the education of the public as well as for study by serious students of fishery science.

Statistics. Statistics provide charts for planning and development which are also essential in tackling research problems. Though statistics is included under the general section, it will get material for its working from all other sections, particularly sections 3 and 4.

2. Pond culture section

Fish-seed problems, spawning habits of Indian carps, 'spawn' and fry traffic ; fish cultural practices, etc. etc.

As the principal Indian carps do not breed in ordinary tanks, so besides improvement in the usual fish cultural practices, attempts have to be made to assure the farmer of a dependable source of fish-seed supply. This will necessitate much research and observation on the spawning habits of carps under natural conditions, semi-natural conditions prevailing in *bundh*-types of tanks and purely artificial fecundation. Problems of setting up rescue stations for saving marooned fish fry in flooded areas will have to be investigated. Correlated with the development of tank fisheries, the problems of tank sanitation, breeding of mosquitoes, etc., will also have to be looked into through a public health fish farming. Fish culture has been employed by several large municipalities all over the world for sewage purification and the consequent production of much protein food. The research station will have to take up this problem almost immediately owing to the presence of extensive sewage irrigated fisheries near Calcutta. Problems of transport and sale of fish in living condition will also receive attention.

3. Riverine and lacustrine fisheries section

Migratory movements of fish and hydrobiological factors arising from the construction of dams and weirs ; irrigation projects and fisheries ; pollution of natural waters by municipal or industrial wastes ; deep-water fishing, etc.

The problems connected with the development of these fisheries are vast and extensive, and ultimately a big staff of statisticians, biologists, water engineers and biochemists will be needed. Such problems as the migratory movements of fishes, hydrobiological and engineering problems arising from the construction of dams and weirs, the pollution of natural waters by the municipal and factory wastes, fish populations, good and bad ways of exploitation, bases of fishery legislation, etc. etc., will need a well-planned and closely co-ordinated teamwork by a band of scientists of diverse affinities. Work should, however, be started on a small scale and gradually expanded.

4. Estuarine fisheries section

Ecology (physics, chemistry and biology of salt water bheries mulletries); problems of open estuaries (estuarine research vessel).

The fisheries problems of the estuaries are divisible into two main categories: (*a*) those of the open estuaries and the creeks connected therewith, and the foreshore, and (*b*) those of the embanked 'bheries' or mulletries. So far as the open estuaries are concerned, they are far away from any habitation and it will be impossible to work them from any centre without the help of an estuarine research vessel. As for the 'bheries,' a field station could be put up at a convenient centre in the neighbourhood of a few 'bheries' and as the salinities in various estuaries are different, experiments and observations will have to be carried out at different centres. Physics, chemistry, ecology and biology of these waters will have to be studied over a number of years before it will be possible to predict the output of these fisheries on any rational basis.

Migrational movements of sea fishes; effects of lesser or greater rainfall; effects of changes of temperature; possibilities of fisheries forecasts and similar allied problems will receive consideration.

5. Technological research section

Problems of fish preservation and utilization of wastes; improvement of craft and tackle, etc.

This section will operate in centres where there will be production in excess of the requirement as food by the local people or people of the area up to which it can be transported in a good condition. The work will have to be taken up simultaneously in the estuaries and the bheel areas while the staff could work jointly on riverine fisheries, especially *Hilsa*.

Besides the problems connected with the preservation and processing of the fresh fish, this section will also look after the improvement of craft and tackle.

The general reaction of fishery scientists in India to these proposals has been that statistics should be raised to a separate section and that more emphasis should be laid on fish technology, especially with regard to the development of riverine, lacustrine and estuarine fisheries of India.

SOME METEOROLOGICAL PROBLEMS IN THE SOUTH-WEST PACIFIC REGION

By J. W. Hutchings, M.Sc. and Dr C. J. Seelye, M.Sc.

PART I

SYNOPTIC

Purpose and Scope

Part I of this paper gives a brief description of those problems in the synoptic meteorology of the South-West Pacific region which, whether they be viewed from a practical or a purely scientific standpoint, seems to stand in most urgent need of solution. These problems have arisen quite naturally out of the material with which the meteorologist of this area has had to work, and are mainly due to the fact that the observed phenomena could not be completely explained by the application of established European and American techniques. The general survey of the characteristics of this region, given in the following section, serves to emphasize the favourable geographical position of New Zealand in the study of the tropical and sub-tropical circulations and to point out the natural field for New Zealand research.

General survey

New Zealand lies roughly between the parallels 35–45 degrees south latitude and is surrounded on all sides by extensive oceans, over which the meteorological elements are known only from the sparse reports from ships and aircraft. In fact, in the whole Australia-New Zealand area there is only one regular reporting station (Campbell Island) south of the 50th parallel and even there we still lack observations from the upper air. On account of this paucity of observational data a detailed analysis of conditions over the more southern parts of the region is hardly practicable at present but nevertheless it should be pointed out from a general point of view that much information useful in high-latitude forecasting can be obtained from a study of southern hemisphere conditions where the circulation pattern is presented in its simplest form. In the south, the zonal westerlies are relatively free from disturbance due to the presence of great continents and it is reasonable to assume that large scale variations in their strength must be due to deep-seated dynamic causes. On the other hand as regards the temperate and tropical latitudes, New Zealand stands in a position very favourable for the intensive study of the tropical and sub-tropical circulations, their complicated interactions and their specific relations to the westerly winds of higher latitudes. Furthermore, in the tropical South Pacific there has been built up an observing network so well distributed and so free from the complications of continentality as to make it one of

the most favourable regions in the world for the study of tropical weather phenomena in their purest forms. That this advantage is very real may easily be seen by a comparison with the northern parts of Australia where continental effects are so pronounced that the primitive circulation patterns are largely obscured and their significance consequently difficult to assess.

The thorough study of the dynamical factors that influence the tropical and temperate circulations in the South Pacific region with special attention to the complex relations that exist between them is thus a natural field for research, and actually we find that it is in this field that most of the recent fundamental New Zealand research has been done.

The main problems for research

The problems which seem to be of most significance for the understanding of basic weather processes in this area are set out in the following paragraphs each section including a brief account of the general development of the ideas. Most of the meteorologists working in the area have contributed in some way to the development of these ideas.

The migratory anticyclone of the Southern Hemisphere viewed as a major wave perturbation

In his paper 'Synoptic Analysis over the Southern Ocean' Palmer put forward the thesis that the pressure trough between two migratory anticyclones of the Southern Hemisphere was occupied by a simple cold front or cold front occlusion to which he gave the non-committal name of 'meridional front.' He also adduced evidence to show that the meridional front was derived as an end-product of the cyclone series in the Indian Ocean and that the migratory anticyclone following the front had its genesis in the outbreak of polar air in the rear of the last depression of the series. It was early recognized that this view of the matter was open to the following objections :

(*a*) The explanation of the large amount of high and middle cloud (sometimes rain) preceding the meridional front, as being due merely to the original upper warm front of the occlusion, was soon realized to be inadequate.

(*b*) The meridional front (or something very much like it) can be traced well into the tropical zone of easterly winds. With the prevailing easterly current it is difficult to see how any frontal surface can move steadily toward the east as the observational evidence requires.

Suggested research. It is suggested, on the basis of (*a*) and (*b*) above, that the phenomenon is in reality a wave-like perturbation of the general westerly current, initiated and controlled by the solenoidal fields associated with the coastlines of the principal continents of the area (Australia, South Africa, South America), and that the cold front is a secondary effect due to the advection of cold air in the rear of the wave. Aspects of the problem requiring investigation are :

(*a*) The explanation, on dynamic and thermodynamic principles, of the system of clouds and precipitation that is associated with the trough perturbation.

(*b*) The explanation of the progressive movement of the trough and the conditions under which it may become stationary or retrograde.
(*c*) The thorough investigation of the so-called extension of the meridional front into the tropics.
(*d*) The investigation of the conditions under which a trough can become cyclogenetic and an investigation of how far the original perturbation is modified by such cyclogenesis.
(*e*) The investigation of the coastal fields of solenoids and their influence in the formation of moving and stationary wave perturbations.
(*f*) The normal variation of the amplitude and slope of the perturbation in the upper air and other problems of the thermal structure of the trough.

The zonal westerlies of the Southern Hemisphere and minor wave disturbances

The study of the trough between two migratory anticyclones as a wave-perturbation soon directed attention to the possibility of minor wave-disturbances in the otherwise undisturbed westerly current, a front being formed only when the perturbations have acquired sufficient amplitude for advective effects to become appreciable. This gave insight into several phenomena that seemed anomalous on a purely frontal hypothesis. Thus, for example :

(*a*) So-called fronts in the zone of the westerlies often seemed to move much faster than the normal component of the wind ;
(*b*) Stationary troughs often appeared to give rise to a series of moving perturbations downstream from the original trough.

Again, quite apart from these considerations, the study of the strength of the general westerly current, most usefully expressed by the zonal index, has lately assumed great importance as offering a promising aid to extended range forecasting in this area.

Suggested research. An extended study of the westerly winds of the Southern Hemisphere, the factors that maintain them and control the variation in their strength, together with an investigation of the dynamics of their perturbations. The following points for study suggest themselves :

(*a*) The variation of the upper air temperatures in the tropics and their relation to the strength of the westerly circulation.
(*b*) The relation between the zonal index and the movement of trough perturbations.
(*c*) The relation of the zonal index to the doubling of the anticyclonic cells in a latitudinal direction and to the number of cells in certain specified longitude bands.
(*d*) The methods by which a stationary perturbation can give rise to a series of moving perturbations downstream from the main trough.
(*e*) ‘ Resonance ’ relations that may exist between the various quasi-stationary troughs often present simultaneously in the Southern Hemisphere zonal circulation.

(*f*) The influence of depressions in the sub-tropics on the formation of perturbations in the zone of westerly winds.
(*g*) The changes as regards deepening, frontogenesis and cyclogenesis which take place when a minor disturbance 'runs into' a major trough and the character of the resulting perturbation.

The flow patterns of tropical and sub-tropical regions

The recognition that the so-called extension of the meridional front into the tropics is in reality a singular line of convergence in the field of motion suggested that the same point of view might usefully be adopted with some of the other phenomena of tropical and sub-tropical latitudes. This led to a complete survey of tropical weather and the eventual formulation of the problem.

Suggested research. An investigation of how far the genesis and evolution of tropical weather can be explained by the kinematics of the field of motion. In this investigation the practical analysis of the wind field should proceed side by side with the theoretical work in order to bring the most frequently recurring patterns into direct relation with those that are theoretically possible on a rotating globe. Special attention should be given to the following points :

(*a*) The formation of singular lines of convergence in connexion with weak areas of low pressure.
(*b*) The influence of travelling disturbances in higher latitudes on the formation of singular lines and points in the tropics.
(*c*) The extension of the present two-dimensional kinematical methods to the case of three-dimensional motion by means of the mean wind components $\bar{u}$ and $\bar{v}$.
(*d*) The use of an extended vorticity theorem to indicate the movement and development of singular lines and points.
(*e*) The investigation of the pressure fields associated with the various singularities in the field of motion.

The upper level depressions of the sub-tropical regions

A phenomenon not uncommon in low latitudes and one which appears very clearly in the northern parts of Australia, is the occurrence of large areas of cloud and rain where the surface synoptic chart merely indicates a zone of easterly winds on the northern side of an anticyclone. Careful kinematic analysis has shown that this circumstance is almost invariably due to the presence of a point or line of singularity at some upper level.

Suggested research. The investigation of the kinematics and dynamics of the non-frontal perturbations or closed circulations in a general easterly current with a view to discovering the conditions which are necessary for their formation and the factors that regulate their growth and decay. Special attention should be directed to the following points :

(*a*) The mean field of solenoids associated with a coastline as one means of producing vorticity and the mechanism for the transference of this vorticity through deep layers of the atmosphere.

(*b*) The investigation of certain preferred levels for the occurrence of singularities in the field of motion and their connexion with the occurrence of certain cloud types.

(*c*) The understanding of the mechanism which controls the increase or decrease of the intensity of the perturbation and the factors influencing its movement.

(*d*) The investigation of the air-mass modifications induced by the distribution of divergence and convergence in the perturbation.

(J. W. H.)

PART II

CLIMATOLOGICAL

The problems in climatology presented by the South-West Pacific area are many and varied, but owing to the incomplete nature of the data they have, for the most part, not advanced to a stage where they may be clearly formulated and attacked. From our experience so far it appears that the main lines of research fall under the headings below :

Rainfall in the tropical Pacific

A narrow belt of the equatorial North Pacific, including Truk, Jaluit and Washington Islands, is featured as a moist zone in the climatological sub-division made by G. Schott. New Zealand research shows clearly that an average annual rainfall of comparable magnitude also occurs in the South Pacific, and should be recognized as another moist zone distinct from the region of the south-east trades. This southern equatorial zone with high rainfall extends from New Britain and the Solomon Islands to its termination near the Northern Cook Group. Between these two moist zones lies the equatorial dry zone which extends eastward from about Ocean Island with increasing spread towards the south.

Suggested research. An extensive study, as precise as the observations will allow, of the distribution of rainfall in the tropical Pacific and its monthly and yearly variations. The following points should be specially examined :

(*a*) The large differences of rainfall occurring within a comparatively small range of latitude.

(*b*) The fluctuations from year to year, especially towards the marginal limits, of the major climatic zones.

(*c*) The fact that, although some of the rainfall variation may be accounted for by a slight general shift of the average pattern, there are times when rainfall shows similar departures from normal over a wide area.

(*d*) The use of stations (such as Penrhyn Island) with a substantial average rainfall (90 in.) but large fluctuations, as sensitive indicators for seasonal forecasting.

Detailed rainfall studies

The mountainous nature of the New Zealand terrain makes necessary a special study of the distribution of rainfall commonly occurring with individual pressure and frontal systems. Special attention needs to be paid to the following :

(*a*) Flood rains and drought periods.
(*b*) Problems connected with soil conservation and river control.
(*c*) The meteorology of forest areas in relation to fire risk.
(*d*) Persistence of pressure types and their connexion with periods of abnormal rainfall. This is especially marked in New Zealand on account of orography.

The climatology of the upper air

As a pre-requisite for any systematic attack on the problem of the general atmospheric circulation in the South-West Pacific region it is necessary to obtain a fairly precise idea of the average distribution of the climatic elements in the upper air. It is only since the beginning of World War II that the increase in the number of aerological stations in the area has provided data adequate to the task.

Suggested action. Determination of the average distribution of temperature pressure and humidity up to the highest level attained by the soundings and their variation from month to month, with special attention to the following points :

(*a*) The solenoidal field associated with the coastline of Australia.
(*b*) The investigation of baroclinic conditions in certain purely oceanic parts of the tropical Pacific.
(*c*) The aerological investigation of the dry and moist zones of the Pacific in relation to the upper air conditions.

Anomalous radio propagation

The North-Westerly Föhn winds of Canterbury offer ideal conditions for the study of certain aspects of anomalous propagation of short wave radio signals. Investigations into this and kindred problems are being undertaken this year.

(C. J. S.)

SOME OBSERVATIONS ON THE HISTOGENESIS OF THE BRENNER TUMOUR OF THE OVARY

By Professor W. A. E. Karunaratne
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In 1907 Brenner reported three cases of ovarian tumour to which he gave the name ' Oophoroma folliculare ' because he believed it to be the most mature form of the folliculoid granulosa cell tumour. He erroneously ascribed the origin of the epithelium to the lining cells of the graffin follicle. In 1899 Orthmann described what we now consider the first case of Brenner tumour under the designation ' fibroma papillare superficiale carcinomatosum ovarii,' but there were several others before him, who under a wide variety of confusing names described ovarian neoplasms which, judging from the descriptions, were undoubtedly Brenner tumours. Such were the cases described by Von Mengershausen (1895), McNaughton Jones (1898) and according to Fothergill (1902) the tumour removed by Sinclair in 1896 and in which ' egg like cells were found among the other cells ' was also of this type. Following Orthmann, several others—Gottschalk (1899), Amann (1899), Schroder (1901), Lounberg (1901), Gottschalk (1904), Voigt (1903), Donald and Fothergill (1902)—described cases. Ingier (1907) described two bilateral cases to which the name ' folliculoma ovarii ' was given, a term very similar to the one Brenner had used. Voigt's (1903) cases were also bilateral.

Meyer (1932) described the characteristics of this tumour and showed that it has no relation to the granulosa cell tumour. He was able to collect only twenty-two cases including four of his own cases, and in the following year Szathmary collected forty, including five of his own. Varangot in 1937 collected 108 cases, including the three cases reported by him, while Fox (1942) found 166 cases reported in the literature, and to these he added four of his own cases. A closer scrutiny of the literature has disclosed the existence of more than fifty cases not included in the series collected by Fox, and to these must be added several cases recorded since then. The writer has also had the opportunity of examining personally seven cases during the last twenty-four years. Six of these cases were slides or specimens sent for diagnosis, but in one instance the complete tumour was sent and a study of this has provided the chief material for the observations in this paper. As most of these tumours are encountered at operations or at post-mortems, it is not possible to make any definite statement as to their frequency.

Age

They occur most frequently in women beyond the menopause, more than 50 per cent occurring in women over fifty years of age. Akagi (1928) reported on a tumour noted in a nine-year-old girl, but the condition is very rare below twenty years of age. It is said to be three times as common

in women over forty as in those below that age. In the series of cases collected by Fox, 79 or 46·5 per cent were fifty-one years of age or over and 41 or 24·1 per cent were between forty-one and fifty years. Five of the patients were between seventy-one and eighty years of age. The tumours are usually unilateral, the right side having a slightly higher incidence than the left. In 137 patients with Brenner tumour, sixty-seven of the tumours were found on the right side, fifty-seven on the left side, whilst thirteen were bilateral. In the case of bilateral tumours both may be of the solid type, or one may be solid and the other cystic.

Morbid anatomy and histology

In general the tumours are small, but they vary within wide limits. Some may be of microscopic size and identifiable only on routine section of the ovary. Specimens of only one or two millimetres in diameter have been recorded (Meyer, Smith and Petit), but examples up to 25 cm. in diameter have been seen (Proescher and Rosasco). Tumour nodules may be found in the walls of enormous cystadenomata. Neiman reported a solid tumour weighing 15 lb and that recorded by Donald and Fothergill was of the size of a coconut. The growths may occur on the surface of the ovary or in the hilus, or they may replace the entire ovary, as in the case recorded by Neiman (1936). In gross appearance and in section the solid tumours resemble fibromata, being hard and fibrous, and when sectioning may impart a gritty sensation. The cut surface may appear somewhat yellowish. Microscopically one sees nests of epithelial cells embedded in dense fibrillar connective tissue. The cell islets are surrounded by a rim of condensed hyaline tissue which is occasionally calcified. The epithelial nests may vary greatly in size and in relation to the fibrous stroma. They may be very small and widely separated or very numerous or extremely bulky. In shape they may be round, oval or cylindrical with knob like formations at the ends. They are composed of large polyhedral cells with oval or angulated nuclei. These cells resemble squamous cells but no intercellular bridges are to be seen.

In most tumours the epithelial nests show a tendency to central cystic degeneration, giving rise to the appearance of ova-like bodies in the cell-masses, and it was this appearance which led Brenner into thinking that these tumours were of follicular origin and was responsible for the designation 'Oophoroma folliculare.' No doubt the resemblance to ova is very marked in many cases. The acidophilic degenerative fluid in the centre of the cell-mass resembles the protoplasm of the ovum and a separated degenerate epithelioid cell lying free in the fluid resembles the nucleus. The cells surrounding the ova-like areas are often radially arranged, and the condensation of the stroma surrounding the islets gives the appearance of a theca and thus the resemblance to a follicle may be very close.

The entire nest may be converted into a tiny cyst with little or none of the original epithelium left, but more often several of the layers persist. The cavity may be lined irregularly by degenerating cells but more often the lining cells are composed of mucoid columnar cells which characterize the pseudomucinous variety of cystadenoma. It has been stated that this inner layer of cells contains glycogen, but no lipoid, and thus differs from the cells of granulosa cell tumours which contain lipoid but no glycogen.

The lining epithelium may be limited to a single layer of pseudomucinous epithelium. This close relationship of the Brenner tumour to pseudomucinous cystadenoma led Meyer to believe that some pseudomucinous cystadenomata originate in Brenner tumours. Mitoses are very rarely if ever found. The contents of the cystic cavity may be mucous or pseudomucinous—a colloid substance mixed with degenerated cells is usually found in some of the smaller cysts.

We may recognize two distinct types of Brenner tumour—there is on the one hand the solid tumour, composed of solid nests of epithelial cells in fibrillar connective tissue, and on the other hand we have pseudomucinous cystadenomata with one or more solid Brenner tumours in their walls. Between these two main types are the mixed tumours with typical columnar and mucous-producing epithelium.

Clinical aspects

The diagnosis of these tumours is based chiefly upon microscopic findings as they have no gross or clinical characteristics which are peculiar to them. The clinical features are those of a slowly growing tumour with none of the features of malignancy. There is one case of recurrence mentioned in the literature, but this is very doubtful.

Most authorities hold the view that the Brenner tumour does not produce any hormone (Schiller, Abraham, Kleine, Freund). A careful search of the literature shows several cases of Brenner tumour associated with post-menopausal bleeding. In some of these cases there was some associated pathological condition which would explain the bleeding. The endometria had been studied in only a few cases of post-menopausal bleeding associated with Brenner, but even in cases where the endometria had been examined and found to be hyperplastic the tendency among the large majority of authors has been to deny an endocrine effect to the tumour. In two cases reported by Fauvet, post-menopausal bleeding was associated with polypoid endometrium, but he states that there is neither clinical nor microscopic evidence that the Brenner tumour is the source of the reactivating substance which he thinks may be attributed to an extragenital endocrine stimulus, possibly from the adrenal. Grayzel and Friedman (1941), in reporting a case of Brenner tumour, remark that a small number of cases present post-menopausal uterine bleeding or irregularity in menstruation with which endometrial hyperplasia is sometimes associated, but they doubt whether this is the result of any endocrine effect upon the endometrium. Taylor states that pseudomucinous cystadenomata have been found to be associated in a small number of cases with endometrial hyperplasia, but he is of the opinion that the hyperplasia is probably the result of a general hyperaemia in the pelvis from the presence of the tumour or possibly also the result of substances elaborated by the cysts or by activated ovarian cells in the cyst walls. As Brenner tumours are sometimes seen in the walls of pseudomucinous cystomata the hyperplasia may well be caused by them. Cases of endometrial hyperplasia and uterine bleeding in association with Brenner tumour have been reported by Schiffman, Te Linde, Lepperetal and others, but the most interesting of such cases is the one reported by Marwil and Beaver (1942) ; their patient, aged seventy-seven, had vaginal bleeding, breast development and an

enlarged uterus with a hyperplastic proliferative endometrium, a combination of signs which leave no doubt of the hormonic activity of the tumour. To quote their words: 'Estrogen hormone production is not definitely excluded as a biologic function of a Brenner tumour since in this case the tumour occurred in a seventy-seven-year-old woman and many of the anatomic and physiologic changes usually associated with the presence of estrogens were found.'

Histogenesis

Although a large literature has grown up about these tumours and our knowledge of their morphology now rests on a sure foundation, the histogenesis of these peculiar growths has remained controversial. Various theories have been put forward at various times in an effort to explain their origin.

Brenner himself believed the source to be the graffian follicle because of the ova-like structures seen so often within the cell-nests and because of the superficial resemblance of the latter to follicles. Further, the condensed ovarian tissue surrounding the follicle was mistaken for the theca folliculi. He considered it to be a highly developed granulosa-cell tumour. It is interesting to note that some years previously Fothergill (1902), who was the earliest observer from Britain to describe such a tumour, expressed a similar view: 'Two views appear to be tenable. They may be true egg-cells or else they may be ordinary cells of the membrana granulosa which have enlarged and grown to the semblance of egg-cells under the same stimulus which has caused the pathological overgrowth of the rudimentary follicle. The fact that two or three of the large cells were visible in many of the epithelioid masses points to the conclusion that the latter view is correct, as one would not expect to find repeatedly more than one true egg-cell in each follicle.'

We now know that there is no connexion between the ovum or follicle cells and the Brenner tumour. The resemblance to an ovum is due to degenerative changes occurring in the epithelioid cells.

Robert Meyer held the view that these tumours arise from 'rests' of the coelomic epithelium first described by Walthard in 1903 and hence called 'Walthard rests.' Meyer believed that these originate from the coelomic epithelium near the Wolffian body from which the epithelium of Muller's duct is derived. The Walthard rest is a small collection of cells which may be seen in the cortex or hilum of the ovary, or beneath the serosa, or within the meso-salpinx. Both solid and cystic varieties occur. They are frequently found. Danforth observed them in 16 per cent of 350 tubes, the 'rests' occurring with equal frequency beneath the serosa of the tube and within the meso-salpinx. In the ovary, the incidence was much less. Danforth found them in only 5 per cent of 100 ovaries. The reason why the Walthard 'rests' were first incriminated as precursors of the Brenner tumour is not entirely clear. Perhaps it is because the Brenner tumours very closely resemble the 'rests.' The origin of the Walthard 'rest' itself is obscure. There are also other views regarding their origin, viz., that they arise as an inflammatory reaction of the peritoneum, from the germinal epithelium or from numerous other structures. These rests, like similar rests in other parts of the body may remain permanently

dormant or may be awakened into activity by a general or local stimulus such as hormone action, change in nourishment or circulation. In this way the ' rests ' may give rise to tumours.

Let us now consider how the evidence supports this theory. No one will deny the close similarity between the Brenner tumour and the Walthard ' rest ' both in the solid and cystic types. It has also been observed that the epithelial changes seen in the Walthard ' rest ' are very much like those exhibited by the epithelial cell-masses of the Brenner tumour. Just as we have pseudomucinous transformation in the latter, cystic Walthard ' rests ' may be lined in part by pseudomucinous epithelium. The striking resemblance of the Walthard ' rest ' to the Brenner tumour is not limited to their morphological structure, but according to Varangot, Danforth and others there is a striking resemblance between the two in nuclear detail in that there is a peculiar folding or grooving of the nuclei in the cells of Walthard ' rests ' and in the cells of the Brenner tumour. Some regard this as a fundamental characteristic, pointing to a genetic relationship suggesting that both are derived from the one tissue. The same nuclear pattern is seen in some pseudomucinous cystadenomata, and as mentioned already, some consider that a certain proportion of pseudomucinous cystadenomata takes origin from Brenner tumours. It must be admitted however that as stated by Arey, such grooving is not specific to these structures but is also found occasionally in the nuclei of connective tissue, smooth muscle and ordinary epithelium.

A serious objection to the theory is that no case of Brenner tumour has been observed in the Fallopian tube although the ' rests ' are commonest here, being found, according to Danforth, three times as often in the tube as in the ovary. Various explanations have been offered for this discrepancy, the customary one being that the tube shows a marked indifference to tumour growth of all kinds, although it contains tissue which in other sites would give rise to various types of tumour. Although such indifference to tumour growth may be true with regard to its own specific tissue yet a ' rest ' such as the Walthard cell collection is should not exhibit this indifference but should respond to stimulation whatever its location. Furthermore, whereas the solid ' rest ' is three or four times commoner than the cystic variety yet in the case of the Brenner tumour, the solid variety is by far the commoner, although cystic hollowing may be seen in some of them. In the literature there are records of many examples of Walthard ' rests ' and of Brenner tumours, but in only a very small number of cases have the two conditions been found together, and even in these few cases no intimate connexion between them has been shown. For instance, Novak mentions a case where he found ' rests ' in the mesovarium with a Brenner tumour in the medulla of the ovary. He says that this is the only case where he found the two conditions in association, but as you will see, there is no obvious relation between them.

Schiller, while holding the view that the Brenner tumour may originate in a Walthard ' rest,' suggested another possibility, viz., that the tumour may originate in the rete ovarii from a persistence of the original urogenital connexion. According to him the Brenner tumour consists of a stroma of fibrous tissue in which are embedded islands of transitional squamous epithelium which may show glandular cavities lined with high

columnar epithelium. He says that the combination of intra-epithelial glands, i.e. mucous glands embedded in stratified epithelium characterizes the uro-poietic system and is found physiologically in the pelvis of the kidney and in the urethra. Some support for this theory is given by Stohr, who records a case of Brenner tumour in which a ' topographical relation ' existed between it and the rete ovarii in that there was an ' intimate weaving ' of rete ducts and the nests of Brenner epithelium. There was a cyst filled with mucus, and this was lined partly by Brenner epithelium and partly by cuboidal epithelium, which forms the usual lining of the rete tubules. There was also a rete tubula distended with mucus without any alteration of the epithelium. The author considers this to be a functional alteration, which may lead to heterotopic tumour formation. The presumption is that these tumours develop from the dislocation into the gonads of germs which primarily belonged to the urinary system. He also mentions a case where a Brenner tumour developed from the rete ovarii. The not infrequent occurrence of Brenner tumours in the hilus of the ovary is also advanced by Schiller in support of this view. While such a concept may conceivably explain the occurrence of a tumour in the hilum of the ovary, it offers no explanation for the large number of Brenner tumours that arise elsewhere, for instance in the ovarian cortex. Danforth also points out that the cells of the rete ovarii and the epoophoron tubules do not show the folded nuclear pattern seen in the Walthard rest and in the Brenner tumour, and considers this finding as evidence against Schiller's theory.

Another view which, though once popular, has now been more or less discarded, is that of Fischel, according to whom the Brenner tumour is derived from the mesenchymal core of the ovary. The conception of ovarian embryogenesis has varied a great deal. According to Fischel all the various structures, viz., the rete, medullary cords, the ova and follicles arise not from the germinal epithelium but from a local condensation of the mesenchyme. Accordingly Fischel is of the opinion that the Brenner tumour as well as the sex-influencing tumours are all produced by mesenchymal condensation, the least differentiated being the Brenner tumour, which has not reached such an extent of development as to produce masculinizing or feminizing traits in the host.

On the other hand, Goodall states that all epithelial structures in the ovary arise from the germinal epithelium and that some of the interstitial cells are derived from the germinal epithelium and some from the connective tissue of the Wolffian body. He also supposes that if the germinal epithelium in the human female becomes invaginated for any reason it would be liable to tumour formation. Lordy's findings are also of importance in regard to ovarian development. From examination of the ovary from a new-born puppy he was able to prove the complete morphological identity between the cells derived from the third proliferation of the germinal epithelium of the ovary and the cells constituting Walthard ' rests,' and further he was able to confirm the presence of the nuclear groove in his own case of Brenner tumour and in sections of the ovarian cortex in the new-born puppy. Another hypothesis is that these tumours arise through a one-sided development in a teratoma. It is based on the not infrequent association of Brenner tumours with pseudomucinous

cystadenomata. A pseudomucinous cystadenoma may contain a solid Brenner nodule in its wall and pseudomucinous epithelium is often found in Brenner tumours. While there is not the slightest doubt of the relationship of pseudomucinous epithelium to Brenner tumours the theory does not hold in regard to the large number of Brenner tumours which are not accompanied by such adenomata or which do not show pseudomucinous epithelium.

Finally may be mentioned the theory which derives the Brenner tumour from metaplastic ovarian epithelium. The surface epithelium of the ovary as we are all well aware is a part of the coelomic epithelium and therefore has the same origin as that which lines the Mullerian duct—the epithelium of which by differentiation develops into the high columnar, ciliated or serous epithelium of the tube, into the glandular epithelium of the cavity of the uterus and into the high pale mucinous epithelium of the cervical canal (Schiller, 1940). One often sees striking metaplasia of the peritoneum and germinal epithelium in cases of peri-oophoritis, with at times the formation of areas of stratified epithelium and cystic structures and thus closely resembling the solid and cystic varieties of Walthard ' rest.' Novak describes a case, No. 7 in his series, where the germinal epithelium beneath a layer of peritoneal adhesions had assumed a high columnar form resembling endometrial epithelium. Goodall states as his opinion that there is no tissue in the human body which can equal the metaplastic power of the ovarian epithelium. Every variety of epithelium has been repeatedly demonstrated on the ovarian surface—columnar, cubical, stratified, mucinous and ciliated. All these types can be seen in sections from the present case. Goodall also maintains that with increasing age and ovarian atrophy, fibrous reaction and replacement fibrosis becomes more common, leading to corrugations of the surface and invagination of the germinal epithelium. It is therefore not surprising that these tumours, the chief pathological feature of which consists of fibrous tissue proliferation about numerous inclusion-like cysts, should be more common beyond the fourth decade and practically after the menopause.

Although most authors are of the opinion that there is no endocrine effect produced by the tumour, yet, as mentioned already, there are several cases on record which appear to point to some such effect. If a hormone can be demonstrated it could be explained on the basis of the tumour originating from the germinal epithelium which, according to the latest theory, gives rise to the follicle cells, the source of the hormone-oestrin.

Since structures resembling Walthard ' rests ' can arise from the germinal epithelium, there is no valid reason why Brenner tumours cannot originate from this epithelium. The coelomic epithelium from which the germ epithelium is derived and, according to Meyer, gives rise to the Walthard ' rest,' is the parent of both. One does not deny that Walthard ' rests ' can give rise to Brenner tumours, but it is not necessary to postulate that every Brenner tumour should have its origin in a Walthard ' rest,' since the germ epithelium of the ovary has the same potentialities as the coelomic epithelium. In the case mentioned by Novak and to which reference had already been made, where a Brenner tumour was associated with Walthard rests there was also extensive endometriosis. As we are well aware, a generally accepted theory of endometriosis is coelomic metaplosia, and

it may well be that in this case the endometriosis, the Brenner tumour and the Walthard rests had a common origin, viz., metaplastic ovarian epithelium.

Scott notes the similarity of the epithelial lining of the cystadenoma and adenofibroma to that of the invaginating surface epithelium and germinal inclusion cysts. There is also to be noted in these cases hyalinization of the fibrous tissue in relation to the epithelium with some calcification in the hyalinized areas ; frequent proliferation of the epithelium simulating the cell-nests characteristic of the Brenner tumour and mucoid transformation of the epithelium of some germinal inclusion cysts. There is therefore a very close similarity between these conditions and the Brenner tumour, indicating that they originate from the same tissue, viz., the germinal epithelium. So close is the resemblance between adenofibroma and Brenner tumour that several cases of Brenner tumour had been erroneously reported as cases of adenofibroma. Such were four of the seventeen cases described by Frankl under the heading 'fibroma ovarii adenoscysticum,' the cases reported by Frankl and Klaften, the case reported by Fleishman as 'adenofibroma cysticum papillare ovarii,' and the three cases of adenofibroma described by Spencer and those recorded by McNaughton Jones, Darwall Smith and Arthur Giles.

Adenofibroma and Brenner tumour also agree in that both occur at a late age period. In thirty-one cases of adenofibroma 93·5 per cent occurred after the age of forty ; 64·5 per cent after the age of fifty, and 29 per cent were over sixty years of age. In 158 cases of Brenner tumour the corresponding percentages were 76 per cent, 50 per cent and 20 per cent. The reason for the late incidence is that both conditions occur at a time when the ovaries are atrophied and fibromatous reaction had taken place, leading to corrugations on the surface of the ovary and invagination of the germinal epithelium.

With regard to the serous cystadenoma, all are agreed that it originates from the germ epithelium. Surface papillomata arising from the germ epithelium are quite common and the invagination of the germ epithelium by these papillomata gives the picture of an early papillary serous cystadenoma. There are also to be found in the literature several instances where a Brenner tumour had been associated with a serous cystadenoma. Smith and Petit (1939) record two cases. In the first case, there was a Brenner tumour of one ovary and a serous cystadenoma in the other; in the second case, in one ovary there was a Brenner tumour associated with serous cystadenoma, in the other a pseudomucinous cystoma. In two cases recorded by Proescher and Rosasco (1936) in the first there was in one ovary a ciliated epithelial cystoma and a Brenner tumour in the other ; in the second case, in the same ovary there was a large serous cystoma and a large Brenner tumour containing pseudomucinous epithelium. There appears to be an intimate relationship between these different conditions.

Proescher and Rosasco (1936) also state that the Brenner tumour is linked genetically with the majority of the serous, partially fibrous and adenomatous and papillomatous cystomata including the adenofibroma. This linkage is no doubt effected through a common origin from the surface epithelium of the ovary.

A direct connexion between a Brenner tumour and the surface epithelium has been recorded by two authors. Meeker states that in his case some of the rests were connected with strands of cells extending from the surface of the ovary. Arey mentions a case of Brenner tumour connected with the surface epithelium of the ovary by a narrow stalk in which it was possible to make out a gradual transformation from the cells characteristic of the germinal epithelium into those of the other.

Fleming states as an objection to the view of the origin of the Brenner tumour from the surface epithelium that no similar cell clusters were found in the surrounding tissue and that no in-growths from the superficial epithelium were seen in any of the tumours examined by her. This is, however, not a general observation, and is contrary to my experience. In the present case we see not only cell clusters and surface in-growths but there are also to be seen various types of epithelium—flat, cubical, columnar, stratified ; mucous charge in the epithelium ; hyalinization in relation to the epithelium, with calcification in some of the byclinized areas. The relationship of the Brenner tumour to the fibroadenoma or the papillary serous cystadenoma has been demonstrated, and evidence has been brought forward indicating that all those structures arise from the germ epithelium of the ovary.

SOIL SURVEYS IN CANADA

By Dr A. Leahey and P. C. Stobhe

Organization

Soil surveys are being conducted in all the provinces of Canada by the Experimental Farms Service of the Dominion Department of Agriculture in co-operation with the various provincial departments and colleges of agriculture. In some provinces soil surveys have been made for some twenty years, while in others this work has been started within the past few years. Generally the headquarters for the soil surveys within each province is at the colleges of agriculture.

In order to facilitate the correlation of the various soils surveyed to date in Canada and in order to bring about greater uniformity in the soil terminology which is in use, a National Canadian Soil Survey Committee has been established. This Committee also deals with various other phases of soil survey work and it is hoped that in time it will improve the soil survey work in Canada and will make it possible to present a clearer picture of Canadian soil conditions. The permanent chairman and the permanent secretary of the Committee are Dominion employees located at the Central Experimental Farm at Ottawa. These men are largely responsible for carrying out the correlation of soil types between provinces and for other work associated with the Dominion headquarters.

Objective

One of the main purposes of the soil survey is to provide an inventory of the Canadian soil resources. Soil surveys are undertaken also to provide a basis for research programmes, planning of production, soil conservation and the solution of special problems.

Types of surveys

The types of surveys which have been made have depended to a large extent on the main objectives, the problems, and on the facilities available.

The soil surveys can be roughly divided into the following four types :

(*a*) Preliminary or exploratory surveys, mainly in unexplored and inaccessible areas. They are made in order to obtain a rough idea where potential agricultural soils are located.

(*b*) Reconnaissance surveys—where it is desirable to obtain a knowledge of the soils of an area as quickly as possible. The intensity of these surveys or the amount of detail which is mapped varies with local conditions. Traverses are usually made at 1 to 3 mile intervals.

(*c*) Detailed-reconnaissance surveys cover an area in greater detail—traverses are approximately ½ mile apart.

(*d*) Detailed surveys—in connexion with the study of special problems on special experimental areas. An endeavour is made to map all visible soil variations. Soils may be examined at intervals of about 100 feet or less.

Areas surveyed

The total acreage which has been covered by the various types of surveys, from detailed surveys to broad reconnaissance surveys, is approximately 202,000,000 acres or over 315,500 square miles. Of this total approximately 139 million acres have been covered by reconnaissance surveys and about $3\frac{1}{2}$ million acres by detailed and detailed-reconnaissance surveys.

A considerable portion of the area covered by the reconnaissance surveys will have to be surveyed by more detailed surveys as conditions warrant it and as facilities become available. The policy is to obtain a general picture of the soil resources of Canada as quickly as possible by reconnaissance surveys. Meantime detailed surveys are being performed in areas where problems are most pressing.

Contributions of soil surveys to agricultural development

Soil surveys are not an end in themselves. Their greatest contribution is in providing a basis for other investigational work. Soil survey information has not been utilized to its fullest extent to date but it is expected that its field of usefulness and its application will greatly increase in the future.

Soil surveys, however, have made important contributions, especially in the prairie provinces, where a larger percentage of the agricultural land has been surveyed than in Eastern Canada. Some of the more important contributions are as follows :

1. *Soil-climatic zones.* The soil surveys have greatly aided in the establishment of the soil-climatic zones, especially in Western Canada where the zones are more distinct and have been more accurately delineated. In Eastern Canada the zones are less distinct and not very accurately established but, nevertheless, they are broadly very significant. These zones provide a safe guide for the zoning of different types of farming which can be practised with reasonable degrees of success and for the zoning of the major crops and varieties. The soil zones are also generally linked with fertility requirements.

The major soil zones in Canada are :

(*a*) Brown soil zone on the dry prairie, best adapted to ranching, some grain growing and to irrigated crops.
(*b*) Dark brown soil zone on prairie, best suited to grain growing, some ranching and some mixed farming.
(*c*) Black soil zone, park land, best suited for mixed farming and grain.
(*d*) Grey wooded soil zone, well suited for mixed farming and grass seed production.
(*e*) Grey brown podsolic soil zone. Adapted to a wider range of crops and diversified types of farming, such as dairying, mixed farming, fruit and vegetable production, etc.
(*f*) Podsol soil zone. Mainly suited for mixed farming and locally well adapted to special crops such as fruit and potatoes.
(*g*) Soils of the Pacific coast. Well suited for intensive farming, such as fruit and vegetable production, dairying and poultry.

2. The importance of the location of virgin land suitable for agricultural development is now generally recognized. At the same time it is just as important to retain potentially sub-marginal land in forest, thus conserving these dwindling resources. Soil surveys have been a great aid in determining the potential possibilities of the virgin lands. They have also been of assistance in locating suitable farms in old established areas for the settlement of war veterans and others.

3. Considerable areas of sub-marginal farmland have been taken out of cultivation in the prairie provinces and regrassed or turned into community pastures on the basis of soil survey information. Similarly the eventual agricultural abandonment and the reforestation of some farm land in Eastern Canada is clearly indicated by soil survey information.

4. Soil conservation and soil erosion control practices must be based on accurate soil survey information. Extensive use has been made of this in the prairie provinces where it has been definitely established that certain soils are more subject to drifting than others. The types of effective control measures vary with the different soils and they have to be applied more vigorously on some soils than on others. A similar situation prevails in connexion with water erosion of soils. In connexion with moisture conservation practices it has been established that the capacity of the different soils, as indicated by the soil surveys, to absorb and hold moisture varies greatly.

5. The application of soil survey information in connexion with soil fertility studies and practices is coming gradually into use. The extent of soil depletion under ordinary farm practices and the required treatments for optimum levels of fertility depend to a large extent on the particular soil type. Experience has shown that much money can be wasted if fertility work is conducted on the main experimental stations without reference to the soil survey maps. It has been found that more fertility work has to be done on smaller substations and on individual farms on various soil types in order to find the correct answers to many fertility problems.

6. The crop adaptability, which varies greatly over broad zones and is also very significant locally due to soil variations, is an important factor in proper land use. Soil survey information has been used to great advantage in this connexion, especially in the case of special cash crops, such as tobacco, orchards, market garden crops, sugar beets, flax, etc.

7. Farm management and economic land classification studies have to a large extent been based on soil survey information as the proper management of the land is intimately related to the nature of the soils in question.

8. The rating and evaluation of the soils is of great importance to all organizations dealing with land. Soil surveys have greatly contributed towards the evaluation of the various soils. Progress along this line of work has been variable depending on the amount of supplementary information available. The greatest advances in this work have been made in Saskatchewan, where rural assessment is now based on accurate soil information, i.e., on the ability of the land to produce crops.

9. Soil survey information has been used very extensively in recent years for the location of irrigation projects in Western Canada. As the installation of irrigation facilities is a costly proposition it is important that only such soils as are suitable for the purpose be irrigated.

10. The location of dug-outs and dams in the prairie provinces has in many cases also been determined from soil survey maps. It is important that such facilities be located on soils which will retain the maximum amount of water and will lose very little through seepage.

11. The limited value of many chemical tests, as an aid to the solution of fertility problems, can be greatly increased if they are more closely correlated with soil types as established by the surveys and with field experiments with different crops on various soil types.

There are many other instances where soil survey information has been used to great advantage and in many cases by people not directly connected with agriculture. Thus the reforestation of certain areas by desired species of trees and the study of tree growth has in many instances been related to the soil types as established by the surveys.

Many requests for soil survey information have come from engineers in connexion with the construction of dams, bridges, drains, ditches, pipe and cable lines highways and especially during the war, for the construction of airports and runways. More recently soil information has been sought by radio engineers in connexion with the location and construction of broadcasting stations.

The application of soil survey information is rapidly increasing as more areas are surveyed and as the information which has been collected becomes available to the public. This basic information can be used to advantage in almost every phase of agriculture and plans should be made to utilize it to the fullest possible extent.

Soil survey methods

In all soil survey work, classification is based on the soil profile. Such external factors as, natural vegetation, condition and kind of crops, slope or position, stoniness, etc., are also observed.

Soil profiles are examined by the aid of a spade or shovel, the auger having only a limited use for testing the subsoils. Chemical field tests are in most cases limited to the use of hydrochloric acid, for the detection of free lime, and to a reaction test kit. All other chemical and physical determinations to check and verify field observations are made in the laboratory.

The mapping units are plotted in the field on topographic maps which are usually on the scale of 1 or 2 inches to 1 mile. In more recent years aerial photographs have been used for this purpose to great advantage, especially in detailed surveys and in broad reconnaissance and preliminary surveys in undeveloped and inaccessible areas for which good base maps are not available. The aerial photographs have the added advantage that, after preliminary ground studies, they can be used to identify the vegetative ground cover as well as topographic variations.

Brunton compasses are used to record the direction of such traverses which are not shown on the map as roads or trails. The distances are measured with cars on the roads or by pacing if on foot. Measuring chains are used very seldom and only on detailed surveys. Slopes are usually measured by the aid of Abney levels. In reconnaissance survey cars are the chief means of transportation. In regions where motor roads cannot be used, pack horses, canoes and boats have been used for transportation

and much of the work is done on foot. In detailed surveys all the traverses are made on foot.

Classification

Any one who is familiar with Canadian soil survey literature probably has noticed a lack of uniformity in the terminology which has been used in connexion with the various mapping units. This may lead one to think that there are great differences in the classification and mapping of Canadian soils. Actually the differences are not as real as they are apparent. The reason why these apparent differences in terminology have become established is that some of the early surveys were started independently by the provinces without Dominion tie-up and correlation. Some of the terminology which was adopted by some of the provinces in the early years has been carried over to the present time.

The main mapping units in Canada are based on the soil profile and its associated environment. This mapping unit is generally the soil type or phase, while in the broader reconnaissance surveys it may be a larger unit. The soil type is defined so as to be essentially uniform in all its important physical characteristics and is the least variable of any of the geographical land units. Soil types which possess considerable range in slope, erosion or stoniness are subdivided into phases.

The soil types may be grouped into soil series. Many series are monotypic but usually a series contains two or three soil types which are essentially alike in most characteristics, but which vary somewhat in texture, especially in the surface soil.

In most provinces the soil series are for convenience grouped in a catenary arrangement. The soils of a 'soil catena' or 'soil association,' as it is called in a number of provinces, have developed from similar parent material within one climatic zone, but they may vary in other soil characteristics which in most cases are associated with drainage conditions and relief. The terms 'soil catena' and 'soil association' as applied in Canada are synonymous. The same holds true for 'soil series,' 'soil associate' and 'soil member.'

Due to the differences in the detail of mapping, in some of the reconnaissance surveys the soils have been mapped as associations or catenas. In such cases the different members or series which make up the associations are described although they are not indicated separately on the map.

The broadest mapping units in Canada are the soil zones and sub-zones. The soil zones are broad areas in which the dominant 'normal' soils belong to a certain great soils group such as, podsols, chernosem, etc. However, a soil zone also usually contains a number of intrazonal and transitional soils groups. The soil zone, therefore, should not be confused with a great soil group, as the zone is a more embrasive mappable geographic unit than the categorical great soils groups.

Similarly all the soils of an association or catena do not belong to one categorical great soil group. The well drained 'normal' members usually represent one of the major zonal great soils groups, while the associated other members usually represent one or more of the intrazonal great soils groups.

In Alberta the various soils have not been designated by names but

instead are referred to by a three digit number in which the numerical figure of each digit refers to a specific soil characteristic. Thus, the figures in the first digit, ranging from 1 to 7, refer to the zonal characteristics of the soil, the figures in the second digit, ranging from 0 to 8, refer to the different kinds of parent materials and the figures in the third digit, ranging from 0 to 7, refer to profile characteristics, such as degrees of development, drainage conditions, salinity, etc. The texture is designated by abbreviations of the textural class, i.e., c.l. = clay loam, etc. Although this system has some advantages in preliminary work it also has some disadvantages when final reports are prepared.

In connexion with the categorical classification of soils, the various series or corresponding units are described and the categorical great soils group to which a particular soil belongs is indicated where possible. A number of the great soils groups which have been recognized and defined by the U.S. Soil Survey also occur in Canada. However, some new zonal great soils groups will have to be defined for North Western Canada and some intrazonal great groups for Eastern Canada.

To date no intermediate category has been established between the great soils groups and the soil series. Such intermediate group, corresponding to the U.S. soil family, is desirable, but to date our information has not been sufficiently complete to permit the establishment and definition of the necessary number of soil families to take care of all Canadian soils.

SOME NOTES ON SOIL MECHANICS IN CANADA

By Robert F. Legget
(University of Toronto)

Soil mechanics is the term now widely used to indicate the detailed field and laboratory studies carried out into the chemical, physical and mechanical properties of soils in relation to their use in civil engineering practice—as foundation media for structures and roads and airports ; as materials of construction in dams, fill and subgrades ; and for a variety of other uses.

The word ' soil ' is used by the engineer to indicate *all* unconsolidated material in the earth's crust, for it is with all this material that his operations are concerned. He therefore uses the word in an entirely different way from the agriculturist, and even from the geologist. This is unfortunate, for it has already led to some misconceptions, especially since agricultural and engineering soil studies have little in common. It is now too late for any change to be made, and the term ' soil mechanics ' must be accepted.

The study of soil mechanics is of relatively recent origin, that is, as an organized branch of engineering inquiry. The first official use of the term, in North America, appears to have been in the title of the First International Conference on Soil Mechanics and Foundation Engineering, held in 1936 at Cambridge, Mass., as a part of the tercentenary of Harvard University. Six Canadian engineers were present at that meeting ; one of them presented one of the papers, and Dean C. R. Young, of the University of Toronto, presided at one of the sessions.

As a direct outcome of that meeting, instruction in soil mechanics was introduced into the undergraduate engineering curriculum at the University of Toronto in 1936. The University of Alberta had already taken this step, Professor I. F. Morrison having introduced into the civil engineering curriculum a course in the mechanics of granular materials as early as 1932. To-day, several of the other universities of Canada include soil mechanics in their regular undergraduate curricula, and some include also some laboratory work on soil testing.

Although Canada is so dependent upon communications, progress in the application of modern soil studies in highway work has been somewhat slow, as compared with corresponding advances in the United States. Four or five of the Provincial highway departments now operate soil testing laboratories in connexion with their work, the most notable being that of the Quebec Department of Highways, located in Quebec City.

Little original work has been done, as yet, in Canada on applications of soil mechanics in road work, the most notable study being that of Dr Norman W. McLeod, of Imperial Oil Limited, into the use of rapid curing bituminous material for ' waterproofing ' fine soil particles, this being

a special and quite successful means of soil stabilization. Soil-cement has been used on a few important jobs in Canada, following techniques developed in the U.S.A. The use of calcium chloride is now common practice in many parts of the country in connexion with the construction and maintenance of secondary roads where soil stablization is used.

A number of Canadian engineers participate actively in the proceedings of the Highway Research Board of the National Research Council of the U.S.A. (J. O. Martineaux, of the Quebec Highway Department, and the writer being members of the Main Committee of the Soils Division). Correspondingly, Canadian engineers have taken some part in the soils work of the American Society for Testing Materials, Mr D. Watt (of the Hydro Electric Power Commission of Ontario) and the writer being members of the main Soils Committee, Committee D-18.

Some of the special investigations carried out in Canada in the field of soil mechanics are as follows :

> the design and construction of the Shand Dam, for the Grand River Conservation Commission in Southern Ontario, the dam being 75 feet high, built entirely of glacial till, containing about half a million cubic yards of soil : soil tests were carried out at the University of Toronto (1) ;
>
> the study of permanently frozen ground and other effects of freezing upon soil at the University of Alberta (2) ;
>
> intensive soil studies for the design and construction of the St Mary's Dam in Alberta by the Soils Division of the Prairie Farm Rehabilitation Administration of the Federal Department of Agriculture (under Mr R. Peterson) ; the work has been described in a paper in the *Engineering Journal*. The same organization has already done a great deal of work on smaller earth dams all over the prairie region of the Dominion (3).

Many other studies have been carried out as private investigations, details of which have not as yet been published. The principal laboratories in which such soil studies have been and can be carried out in Canada are as follows :

> University of Alberta, Edmonton ;
> P.F.R.A. at the University of Saskatchewan, Saskatoon ;
> Hydro Electric Power Commission of Ontario, Toronto ;
> University of Toronto ;
> Department of Public Works, Canada, at Ottawa ;
> Ecole Polytechnique, Montreal ;
> Quebec Department of Highways, Quebec City.

Practically all academic soil study has naturally been at a standstill for the last few years, being subordinated to essential war work. Arising from inquiries from the Canadian Army, however, in connexion with wartime operations of fighting vehicles, an Associate Committee of the National Research Council on Soil and Snow Mechanics was organized early in 1945. The Committee was a joint venture of the Canadian Army and the National Research Council. To date, its activities have

been almost wholly confined to studies of the interrelation of soil mechanics and the design and operation of track-laying vehicles (4).

The Committee has made some studies of snow and has observers on the Musk-Ox expedition to the Canadian Arctic, specially trained in determining snow characteristics. It is planned to extend the work of the Committee in relation to 'snow mechanics' (an almost untouched field) and also to the study of 'muskeg,' the organic material which covers so much of the northern parts of the Dominion.

It is hoped that in the near future this Committee may still further extend its activities into the field of civilian soil mechanics studies and serve as a clearing house for information in this field of study for the Dominion, linking together the relatively few workers in the field and, so far as possible, preventing useless duplication of effort. Through the Chairman of the Committee, and its members, it is hoped to maintain contact with workers in soil mechanics in the U.S.A. (as through the A.S.T.M. and the H.R.B.) and correspondingly with British workers in soil mechanics, notably through publications of the Institution of Civil Engineers.

The geology of Canada is such as to give rise to many special soil problems in connexion with engineering work throughout the Dominion. Past experiences, some of them unfortunate, substantiate this suggestion. Despite the limited resources available to workers in this field (limited in relation to the size of the country and the magnitude of some of the problems to be faced), it is confidently hoped that in the years which lie immediately ahead, Canada may be able to make a real contribution to the progress of the engineering study of soils.

References

(1) McQueen, A. W. F. and McMordie, R.C. 1940. 'Soil Mechanics at the Shand Dam,' *Engineering Journal*, Montreal, **23**, 161.
Legget, R. F. 1942. 'An Engineering Study of Glacial Drift for an Earth Dam, near Fegus, Ontario,' *Economic Geology*, New Haven, **37**, 531.

(2) Hardy, R. M. and D'Appolonia, E. 1946. 'Permanently Frozen Ground and Foundation Design,' *Engineering Journal*, Montreal, **29**, 4.

(3) Peterson, R. 1945. 'Soil Mechanics as applied to P.F.R.A. Problems, with special reference to the proposed St Mary Dam,' *Engineering Journal*, Montreal, **28**, 274.

(4) The Committee has issued four publications to date, but as these are still classified as 'Confidential' they cannot be listed.

SOIL MECHANICS IN NEW ZEALAND

By E. H. Lovatt, B.Sc., A.M.I.C.E.
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1. Arising from investigations in New Zealand the following observations may be noted :

(a) A proper picture of the proposed structure and its soil foundations within the seat of settlement is an engineering necessity.
(b) Records of the physical properties of soils and a sample library is a valuable engineering reference.
(c) Settlement of existing structures should be recorded and the failure of soils structurally applied to check the behaviour of soils.
(d) The popular small field loading test, while useful in pavement design and small structures, is no substitute for the modern sampling and laboratory testing technique when deep-seated settlements are to be considered.
(e) The average shear and compressibility calculated from a field load test agree with results from laboratory tests on samples taken from within the pressure bulb.
(f) Dynamical pile-bearing theories may conflict with the fundamentals of soil mechanics and should not be applied rigorously where—

   (i) cohesive formations underlie the pile points.
   (ii) piles are clustered in cohesive formations.

   In such cases the effects of pressure bulbs from piles must still be considered.
(g) Close co-operation of the practical engineer with the scientific specialists of the soil mechanics laboratory is essential.
(h) Considerable economy can be achieved by a rational approach to foundation problems.

2. The value of soil mechanics to engineers lies in the economies achieved by the maintenance of reliable 'factors of safety' consequent on the elimination of certain 'factors of ignorance.' This reduction in guesswork when soils are used as the buried link of a structural chain is the better appreciated since plastic and granular as well as the elastic properties of materials have been given due regard. The universality of this new science appeals to engineers by allowing soils to be used rationally as structural materials whose stability and deformation may be estimated with reasonable accuracy.

Analysis, however interesting, is not an end in itself, and research should be directed to provide simple and usable tools to be employed for better construction. Broadly the aim is to rationalize and maintain an adequate

and economic factor of safety over the entire construction by investigating the underground stress paths and estimating the strains resulting therefrom.

Statically indeterminate frames of steel or reinforced concrete are favoured forms of earthquake resistant construction in New Zealand, and their increasing use makes a clear picture of soil behaviour of particular value.

The deformations and settlements in foundations are realities which must be faced and allowed for in the remainder of the structural link (the superstructure) by including where necessary—

(*a*) *neutralizing measures* in the shape of articulations (structural or elastic hinges) ;
(*b*) *corrective measures*—jacking, etc.

The structural repercussions arising from strains in foundations have been given some attention, and there seems scope for a correlation between the probable earth movements (settlements) and those held limiting in the superstructure.

3. The typical sequence adapted to the New Zealand plant available for foundation analysis is set out below :

(*a*) *Site survey*
- (i) Topographical survey
- (ii) examination of existing structures in vicinity
- (iii) examination of available boring records in vicinity
- (iv) examination of available geological data.

(*b*) *Variability survey*
- (i) Rapid and inexpensive bores with ample small samples
- (ii) ground water conditions
- (iii) Atterberg tests
- (iv) unconfined field compression tests
- (v) three dimensional picture of whole site
- (vi) locations for undisturbed sampling.

(*c*) *Undisturbed sampling*
- (i) Sampling at determined points in large bores
- (ii) consolidation tests
- (iii) triaxial compression tests
- (iv) shear box test.

(*d*) *Engineering tests as required*
- (i) Field loading tests
- (ii) test piles.

(*e*) *Analysis of underground stress conditions from tentative proposals*
(*f*) *Estimation of stability and settlement*
(*g*) *Revision of proposals.*

4. The principles of soil mechanics have been applied to railway problems as under—

Quantitatively

(*a*) Stability of shallow raft foundations of buildings and bridges
(*b*) settlement predictions of shallow raft foundations of buildings and bridges
(*c*) stability of embankments and cuttings.

and *Qualitatively*

(*d*) review of piled foundations
(*e*) investigation of landslides.

Fields for the application of soil mechanics in New Zealand are limited only by the lack of equipment, and as yet no satisfactory portable boring plant for sampling variable strata in inaccessible sites has been procured.

The problem of maintaining the stability of the roadbed supporting the permanent way is increasing in importance with increase in loads and speeds on railways, and this problem will require the application of the principles of soil mechanics to ensure satisfactory solution.

SOIL SURVEY IN THE UNION OF SOUTH AFRICA

By C. R. van der Merwe
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In 1920 a Soil Survey Section of the Division of Chemistry of the Union Department of Agriculture was decided upon; it started to function only in 1925. During the twenty years of its existence its activities have been confined almost entirely to policy. The areas of the individual schemes and projects investigated vary from a few thousand to 300,000 acres and more. The field data of these undertakings are normally plotted on plans (scale 1 in. : 500 ft) on which (*a*) the soil types, (*b*) Brak distribution, (*c*) pH-variation and (*d*) irrigable values or land classification are given. The system followed has been described in the Imperial Bureau of the Soil Science's Technical Communication No. 15, Soil Survey for Irrigation Purposes in South Africa. The Irrigable Value Plan together with the Soil Survey Report is considered confidential and belongs to the Department of Irrigation. The intensity of the field investigations depends on the fact whether the ground will be utilized for closer settlements or for improving and stabilizing existing farming activities.

Thus far no systematic Soil Survey of the Union has been undertaken, because no provision has yet been made for these studies by the Government. The soils of South Africa have, however, not been forgotten and soil data have been collected whenever the opportunity has offered itself As a result of the reconnaissance soil survey the soils of the Union and adjoining territories have been divided into twenty-five groups and sub-groups. These have been described in detail in 'Soil Groups and Sub-groups of South Africa,' Department of Agriculture and Forestry, Science Bulletin 231, and their distribution has been given on a soil map.

Now that the general or reconnaissance soil survey has been accomplished the detailed sub-divisions into smaller sub-groups and in soil types should be the next step. The reports and maps of a detailed soil survey of the country would be of considerable value in demarcating regions where the interests of the population are linked together by a similarity in soil conditions and agricultural activities. As the modern tendency is to plan future developments largely on the regional basis it would appear that the undertaking of a systematic survey of the soils of the Union should no longer be delayed.

PROBLEMS OF APPLIED GEOPHYSICS IN THE DOMINION OF NEW ZEALAND

By N. Modriniak

INTRODUCTION

The Geophysical Survey Branch was organized in New Zealand in 1932 by the Department of Scientific and Industrial Research. Initially, geophysical prospecting was regarded as in the nature of experiments only with the purpose of providing a background whereon to judge the value and the limits of various methods and to develop improvements in apparatus and technique. Its application was stimulated by the increased demand for gold during the depression. Various problems have been investigated as they arose. Progress was retarded by the lack of literature on subjects investigated. The want of a general geophysical publication permitting the interchange of experience and results is regrettable, and also the absence of a research institute on applied geophysics with provisions for intensive courses of study. *The creation of a British pool of instruments under the control of an Institute of Applied Geophysics would greatly assist in problems of regional research.* In the proposed study of New Zealand volcanism and associated phenomena, instruments of precision are essential. The Department has at its disposal three vertical magnetic field balances by Schmidt, one 15-channel seismic refraction and reflection equipment, generators for inductive and potential electrical investigations, one geophysical megger and one Jones seismometer.

BRIEF REVIEW OF PAST INVESTIGATIONS

Field work was commenced in New Zealand in 1933 and was directed toward assisting the alluvial mining industry. The rich placer deposits that were worked in the past were, in general, confined to well defined river channels and became unworkable owing to the increased overburden or the disappearance of the channels below alluvial flats. It was the purpose of the survey to locate these channels, to determine their depths, and the nature of rock in which they are enclosed. In a locality near the township of Cromwell the buried channels were at a depth of approximately 150 ft and the bottom was formed of sandstone and Otago schists. The obvious physical characteristic that permitted a successful search was the difference of elasticity between the overlying gravels and the underlying rock. The speed of transmission of sound waves in the overburden varies between 1,200 and 1,800 ft per second, and from 800 to 1,200 ft per second in the bed-rocks. The seismic refraction method was developed for shallow deposits to a high efficiency. Miles of cross-sections were

observed and different channels traced. This work was supplemented by magnetometer observations. The Standard Dip Needle and the Schmidt magnetometer were used. The heavy ferro-magnetic minerals associated with the alluvial gold were in many places in sufficient quantity to permit their detection by magnetic observations. Difficulties that were encountered by this method resulted from the nature of the alluviation of the plains, for concentration of iron-sands belonged to more recent periods than the eroding of the channel searched for.

Problems connected with lode mining were attempted at a later stage, and the West Coast of the South Island was selected for this study. The quartz veins occur in greywacke, and are embedded in zones of kaolinization: this permits a ready detection of the fracture by electrical methods. It was impossible, however, to determine by this method the presence or absence of the quartz itself. The writer believes that ideal physical conditions exist for determining the presence of such discontinuities as zones of kaolinization and quartz reefs by seismic reflection and refraction.

Entirely different characteristics were met in the Waihi gold-mining fields. The lodes there occur in zones of propilitization in andesite. It was observed that the ferro-magnetic minerals in these zones were chemically altered from tri-valent to bi- and uni-valent iron compounds, resulting in an appreciable loss of magnetic property, and consequently are associated with areas of low magnetic relief. An alluvial sheet underlain by wilsonite covers an extensive area ; and the contacts between it and the andesites was determined seismically. By using the potential drop method it was possible to determine the extension of the Sylvia lode under the wilsonite and alluvial covering. Physically closely related to the former study was the investigation of the mercury deposit at Puhipuhi. It occurs under a basalt cover 50 to 200 ft thick. Concentrations of cinnabar are indicated magnetically in localities of low magnetic relief owing to thermal alterations of ferro-magnetic minerals in basalt.

The serpentine deposit of Takaka was also magnetically studied ; and here, too, low magnetic relief was associated with intense serpentinization.

The Kotuku and Taranaki oil seepages, which were regarded as indicators of a potential oil source, were seismically studied. The great depth to which the sediments extended made it imperative to obtain seismic reflection equipment.

The iron-ore deposits of Onekaka were investigated by the refraction seismic method. The purpose of the investigation was to determine the limit of the limestone on which the major portion of the iron-ore deposit rested.

Water supply problems were studied in the Masterton area ; and the megger earth tester was used. An improved adaptation of this instrument is being considered.

Although the thermal regions of New Zealand extended over many square miles only minor areas have so far been investigated. In an area near Tokaanu, where natural springs indicated the presence of commercial amounts of borax, holes were drilled in areas of low magnetic relief with good results. In the areas surrounding the township of Rotorua 16 square miles were closely magnetically observed. The result of these investigations proved of great value when it was found necessary to keep the Spa supplied

with thermal water by drilling. Areas of low magnetic relief were associated with thermally active zones.

Relatively new is the application of geophysical methods to problems of engineering. For several field seasons extensive investigations were carried out on the study of dam-sites connected with developing hydro-electric power. The majority of them have been selected in welded tuffs, which are relatively highly magnetic. Magnetic observation revealed stress patterns and alluviated river channels, Seismic refraction shooting determined the depths and correct location of buried channels and the contacts of different sheets of ignimbrite. Small fractures near the dam-site itself are located by the potential drop method ; and this indicates zones for future grouting.

Mount Ruapehu volcano suddenly became active and aroused local and widespread interest. A geophysical observatory was established there. Geophones were placed at intervals of approximately two miles from the chateau which is six miles from the crater to the mountain and one was buried in the crater wall itself. They had a frequency response from 5 to 500 cycles and were connected with amplifiers, which in turn fed into a loud-speaker system, thus making it possible to hear crater explosions and the issuing of steam. These were installed to locate focal points of seismicity calculated from the times of arrival at different observation stations.

A self-recording magnetic flux-meter connected to a search coil was intended to record the magnetic flux change due to penetrating lava flows or remelting of rock columns by hot gases in the pipe leading to the crater.

It was appreciated that the basis of comparison between active and dormant volcanism is in the observations that are recorded during both periods, and for this reason it was strongly recommended that we endeavour to set-up bench marks and bases for recording. Precision instruments such as pendulums, gravimeters and absolute magnetic instruments are needed for this purpose.

The Taranaki basin and parts of Poverty Bay were covered by gravity meter reconnaissance during 1938–1939 ; this survey provided revealing data on the subsurface geology, such as buried structural ridges of high basement enveloped by Tertiary marine sediments.

SOIL MECHANICS

(Prepared by the National Road Board of South Africa)

Introduction

This report indicates the field covered by the National Road Board in connexion with the application of soil mechanics to road construction. Our main problems are concerned not only with the design but also with the control during construction of embankment, subgrades and base courses for a programme which involves the construction of many thousands of miles of national road.

Design

The method of design in use in the past has been based on the Atterberg and other indicative tests. Later it was found desirable to introduce a strength test and the test which has been found most suitable is the California Bearing Ratio test. The investigational work carried out so far on various soils has determined the relationships between this strength test and density, moulding moisture, compactive effort and swell.

It would seem that soils should possibly be divided into two classes for construction purposes depending on their swell characteristics. For soils having a swell greater than 20 per cent or a plasticity index greater than 25 per cent, namely, Montmorillonite clays, etc., no appreciable strength increase is obtained with increase in density.

However, considerable increase in swell is obtained with density increase, particularly at low moulding moistures. This feature is undesirable. Consequently the procedure now recommended is not to disturb these soils by compaction or otherwise when they are met in their natural state. With disturbed material such as a fill the compaction is only done to 95 per cent Proctor at a moisture of Proctor optimum.

For soils having swell characteristics smaller than the above the procedure is to design on the strength characteristics resulting from a sample which is compacted at a moisture content 1 per cent dry of modified A.A.S.H.O. optimum and an effort between Proctor and Modified A.A.S.H.O.

In connexion with this recently adopted design procedure it would be most interesting to hear what procedures are being followed in the United Kingdom and the other Dominions.

An alternative method of design is being investigated. For this a total allowable distortion of 0·2 in. has been taken. The deflection occurring in an elastic system consisting of two materials with different moduli of deformation, i.e., a two-layer system, is determined from a triaxial shear apparatus. This is combined graphically with the settlement the load causes in order to give the base course thickness. The shear sample size is 4 inches diameter by 8 inches long and the consolidometer sample used to determine the settlement is $\frac{3}{4}$ inch thick by 4 inches diameter.

Field control

The method in use at the moment consists of determining the wet density and taking moisture samples. The latter entails several hours' delay before the results are known. In order to have this information available, even within 1 per cent, more rapidly a method of electrical moisture determinations is being investigated. An A.C. current is used to eliminate the polarization effect at high moisture contents. When used the apparatus is calibrated the day before application on a material by establishing the moisture-resistance curve with the moistures determined in the usual way. Results to date indicate that density variations caused by changes in compactive effort from Proctor to Modified A.A.S.H.O. result in only about 1 per cent variation in moisture determinations. Errors due to variation in salinity in the days length of road may prohibit the use of the method in certain areas. Errors due to temperature can be eliminated in sampling technique. The method would appear to be more accurate than the use of a pycnometer.

BIOLOGICAL ASSAY—(INSECTICIDES)

By Dr T. J. Naude

Up to the present it has been customary for any one developing an insecticide to establish efficacy by a testing method of his own choice. In practice, therefore, every scientific worker proceeding to work critically on any insecticide that has gained comment elsewhere is obliged to conduct his own test *de novo*, specially as actual experimental method is often left out in résumés or for that matter original publication. It follows that if a standardized system could be arrived at for testing the killing value of insecticides much time and labour could be saved and that a statement of results in terms of such standard tests would automatically serve to assign definite values to the qualities of an insecticide wherever the basis of such testing is known and accepted.

In recent years some attempt in this direction has been made in certain countries, notably the United States of America. The main result has been the evolution of standard tests of the Peet Grady type for contact insecticides especially in the fly-spray group. For other insecticides, both of the dust and liquid type, progress thus far is less advanced yet various individual efforts in this line are tending towards a uniform method of applying dusts and sprays to test insects on a basis representing known dosages per acre.

What is badly needed is the further amplification and crystallization of both groups of methods towards definite technique and standards internationally recognized. Standardization would, of course, be essential not only in mechanical technique and chemical quality of insecticides, but above all towards using for such tests biological material which would be thoroughly comparable throughout so as to obviate vitiation of results through this factor. There are bound to be difficulties at times, for instance the same species of insect may not be equally readily available as test material for different localities or countries, or the local representatives of the same species may differ in relative susceptibility. The disability might, however, conceivably be remedied by counterchecking through exchange of material from time to time. In any case, the final discrepancies attendant on this scheme are likely to be much less marked than they are at present in the relative absence of any accepted standard.

As to means of achieving the practical evolution and adoption of standards, it is felt that specialist interstate conferences between closely associated units such as e.g. the members of the British Commonwealth might very profitably commence discussion through delegates well prepared for the purpose for some time in advance. Then, should matters in such a circle progress satisfactorily, the scheme could be extended for action by similar conferences called on an international basis.

PEST CONTROL—(INSECTS)

By Dr T. J. Naude

Systematized pest control may be regarded as having had its origin in the advent of chemical insecticides, an era, as it were, commencing with the discovery of useful arsenicals many years ago and progressing steadily to the peak represented by the vast range of insecticidal materials available to-day. Whilst the latter continue to develop in unhampered variety, there arose within the past few decades the school of biological control. This was not necessarily an opposition school but was based on the concept of restoring the balance of nature normally broken up when pest species are transported to new areas where their normal natural enemies have not accompanied them. The idea was, however, also extended to the use of indigenous insect parasites and predators, the main difference being this ; in this case releases of the beneficial insects have in most cases to be repeated annually, whereas with new introductions from abroad the natural multiplication and maintenance of the insects are normally relied on. In the latter case particularly, control has on occasion proved so ridiculously cheap as well as striking in effect as to evoke wide and active interest in biological control as an approach to the practical solution of pest problems.

Because, however, in many cases biological control has for various reasons not proved feasible, chemical warfare against pests has continued and increased in intensity and it is significant that in some cases where the tempo of its use has been highest the practical results have deteriorated strikingly. In a few cases the reason for such deterioration has appeared to be traceable to the development of resistant strains of the pest—whether the resistance is actual, or whether the reason for the increased incidence is to be sought rather in the survival and perpetuation of the more vigorous and more reproductive individuals constitutes no difference in practice. In either case, however, it has on occasion become absolutely essential to resort to some change of method. In the resultant studies the serious depletion of the entities of biological control as a direct result of assiduous and prolonged application of poisons has been demonstrated.

Concurrently there has been wide enough interest in biological control on its own account to initiate the critical study of the factors involved in biological control and the manner in which they tend to operate, and this has resulted in a school of thought rather strongly opposed to the use of chemical control, on scientific and practical grounds, particularly as proof has been adduced to show that a chemical method operating against a certain pest on a catastrophic scale is liable to result in the stabilizing of the pest population at a markedly *higher level* than before in spite of continued treatment.

Both trends of events have stimulated redoubled interest in biological control and because biological control must almost of necessity be ex-

pected to yield a lower degree of practical efficiency than the more efficient methods of chemical control the immediate effect is tending towards a policy—as yet largely theoretical—of judicious spraying and dusting in such a manner as to retain useful biological complexes in as unscathed a condition as possible. The indications at present are that the primary producer may be obliged to accept under such a policy a lower degree of efficiency in return for greater stability of control. However, in cases where chemical control has grown to reach absurd demands, as for instance in dealing with the codling moth situation in the Union, the indications are that even if a very considerable proportion of the crop were to be sacrificed in conjunction with the use of biological methods such loss would be largely, if not completely, offset by contingent saving on spraying expenses.

Everything considered, the adoption in general of a policy of judicious application of chemical control seems inevitable and the need thereof is exceptionally accentuated by the advent of such widely effective insecticides as DDT and Gammexane, which seem to promise particular havoc against beneficial insects. This will also inevitably render a much wider and deeper knowledge of the ecology and physiology of individual pest species indispensable and in this manner tend to force the issue at an early date of providing facilities for thorough basic research on a wide scale which, after all, should have been the policy from the outset instead of past policy which, through being satisfied with hasty and superficial palliatives, has been the real cause of the present dilemma.

As to procedure in the execution of control measures, the issue is tending to become so technical and involved that it will probably become increasingly difficult for the lay producer to put chemical or biological measures, or, particularly, a combination of the two, into effect and the indications are that a solution may have to be sought in the establishment of specialist organizations which would undertake control work on contract except perhaps in countries where state action in this field is favoured.

DEVELOPMENTS IN SOIL MECHANICS INCLUDING ENGINEERING DEVELOPMENTS

By J. J. O. Pazzi
(Division of Soil Conservation and Extension Department of Agriculture, Pretoria, South Africa)

Soil mechanics in South Africa, as applied in agriculture, are greatly influenced by the comparatively short and irregular periods of optimum workability. Although there may be short periods of excessive wetness, during which any operation will lead to the loss of the structure by puddling, the major portion of the year is characterized by a lack of soil moisture, resulting in increased draught requirements and lowered effectiveness of soil shifting, disintegration and preparation generally.

On account of moisture being the limiting factor, every effort is made to reduce evaporation and restrict the run-off resulting from the generally high intensities of rainfall, thereby prolonging the period of good workability. To make full use of the short periods of workability, the tractor, more especially the medium to high powered one, is steadily gaining ground. Besides the normal field practices which aim at conservation of soil moisture, these efforts are augmented by the construction of contour banks and catch-water dams, which latter are also used for stock watering and irrigation during dry periods.

In consequence thereof, the following developments are taking place :

General agronomy

(*a*) On account of the high rainfall intensities, the field remains in plough-sod as long as possible in order to increase its water holding and absorptive capacity. In order to reach the optimum of effectiveness, the idea of straight cultivation is abandoned in favour of cultivation along the contour.

(*b*) To minimize the cementing (puddling) effect of raindrop splash and impact, and the undesired evenness of the field resulting from unrestricted raindrop impact, the mulching practice should be more generally adopted.

(*c*) Very often, only light rains occur during the spring, necessitating ploughing on dry subsoil, thereby creating an almost impervious hardpan at the plough bottom, resulting in a reduction of the infiltration rate and an increased run-off. These effects demand a much more liberal and general application of sub-soiling than hitherto practised.

(*d*) Whereas it was formerly the practice to prepare an even seed bed the policy of building up contour banks by a definite system of ploughing is now being gradually brought into application.

(*e*) Whenever the soil is exhausted or scoured by run-off the rate of erosion is such that the gradual building up of contours as described in (*d*) above is too slow a process. In these instances the faster method of construction of contour banks by means of drag ditchers, drag scoops, wheeled graders and terracers is generally applied. Both animal and power traction are used in these operations.

(*f*) Because contour banks are set out on a slight gradient (for safety's sake), it sometimes happens that considerable effluence has to be dealt with. Apart from this, run-off also occurs on the natural pasture down hollows and valleys. More often than not, sites are found which lend themselves to the construction of storm water dams, involving soil shifting ranging from hundreds to tens of thousands of cubic yards. This is achieved by employing drag scoops, rotary scoops drawn by animals or small to medium-sized tractors. Larger projects include the use of more powerful traction and heavy carry-all scrapers. Since the scarcity of labour and the erratic behaviour of the climate do not favour the use of animal traction, the use of heavy machinery is steadily gaining ground. The recent inauguration of conservation areas, primarily operated by the state, will undoubtedly increase this trend.

MINOR ELEMENT DEFICIENCY IN NEW ZEALAND

By Sir Theodore Rigg, M.A., M.Sc.
(Director of Cawthron Institute, Nelson, New Zealand)

During the past twelve years great progress has been made in New Zealand in the identification of minor element deficiencies which, in the past, have been responsible for serious ailments of both stock and plants.

Perhaps the most spectacular result of the minor element investigations conducted in New Zealand was the demonstration that 'bush-sickness' and Southland lamb ailment were caused by a deficiency of cobalt in the food of the animals. Another result of great importance to the stock industry was the more recent demonstration by the Department of Agriculture that 'peat scours' and unthriftiness of stock resulted from a deficiency of copper and could be controlled by the administration of copper sulphate.

Similar work has been carried out on deficiency of minor elements affecting adversely the growth of plants. The identification by officers of the Department of Scientific and Industrial Research and of the Cawthron Institute of certain physiological ailments of apples, apricots, plums and grapes as boron deficiency diseases has been of great value to the fruit industry in both Nelson and Central Otago. Similar work conducted by the Department of Agriculture and the Cawthron Institute on 'brown-heart' of swedes and turnips and 'mottled-heart' of mangolds has demonstrated that these defects result from deficiencies of boron which are extensive in Southland, Nelson, Central Otago and the Waikato. The investigations have shown that these ailments of root crops can be controlled by the use of borax as a soil top dressing. The presence of magnesium deficiency both in tobacco and in apple orchards in the Nelson district have been established and the investigations have shown that in both cases the deficiency symptoms can be overcome by the use of ground dolomite. So far manganese deficiency has not proved of common occurrence but a mottling of citrus leaves in North Auckland orchards has been controlled with sprays of manganese sulphate.

Work on iodine deficiency has been continued by the Otago Medical School. The use of iodized salt has proved of great value in overcoming the incidence of goitre. One of the interesting developments in connexion with the work on goitre has been the discovery that certain plants have positive goitrogenic properties. In the case of brassicas which cause thyroid enlargement, the positive agent inhibiting thyroxine synthesis is now known to be a substance chemically related to thiourea. A more detailed account of this work appears in another paper by Dr C. E. Hercus of the Otago Medical School.

Cobalt deficiency

Following closely on the announcement by South Australian workers that cobalt had beneficial properties in the treatment of 'Coast disease,' New Zealand workers, who had already shown that iron was not the potent factor in the benefit received from the use of certain iron compounds and soil 'licks,' quickly demonstrated that cobalt salts gave a complete cure of 'bush-sickness' at Glenhope, Nelson and of lamb ailment in Southland. The demonstration of the beneficial properties of cobalt salts in overcoming these stock ailments in the South Island was quickly followed by similar success in the treatment of 'bush-sickness' on the pumice soils of the central territory of the North Island.

The elaboration of a suitable technique by New Zealand chemists for the estimation of minute amounts of cobalt in soils, plants and animal organs quickly resulted in overwhelming evidence of an actual deficiency of cobalt in the soils, pastures and animals in those locations where stock ailments of this type were encountered.

Some of the analytical data obtained by the chemists may be reviewed briefly in the following tables :

TABLE 1

Cobalt status of New Zealand soils (extracted with strong HCl)

soil type	cobalt p.p.m. Co.	ailment
Kaiteriteri loam, Glenhope, Nelson	0·4	affected
Kaharoa volcanic ash . .	0·8	,,
Taupo ash (North Island) . .	1·5	,,
Pakihi soil, Westport . .	0·3	,,
Morton Mains, Southland .	4·8	,,
Nelson soil	43	healthy and beneficial
Bluff soil	45	healthy and beneficial
Taranaki soils (average) . .	11·7	all healthy

TABLE 2

Cobalt status of pastures and livers of sheep

material	cobalt p.p.m. Co.	description
pastures . .	0·02 to 0·05	unhealthy
pastures . .	0·07 or higher	healthy
livers . .	0·025	from affected sheep
livers . .	0·165	healthy sheep, freezing works
livers . .	0·20	drenched with cobalt chloride

The analytical data show conclusively the association of stock ailment with low cobalt figures in the soil, in the pastures and in the livers of affected sheep.

Examination of the iron compounds and soils which had proved effective in the treatment of 'bush-sickness' likewise showed exceptionally high figures for cobalt, frequently exceeding 40 p.p.m. while those iron compounds, e.g., Parapara limonite, Onekaka limonite and spathic iron ore from Huntly, which had proved ineffective in the treatment of affected animals, contained very little cobalt.

Use of cobalt in affected districts

A great deal of attention has been paid to methods of using cobalt salts in overcoming 'bush-sickness' and Southland lamb ailment. Drenches and salt licks containing 4 to 8 oz cobalt sulphate per ton of lick have proved valuable in the treatment of stock affected with ailment but the incorporation of cobalt sulphate in superphosphate which is widely used for topdressing pastures has been the chief means for overcoming the trouble and rendering very large areas of suspect country capable of intensive farming both for dairying and fat lamb production.

New Zealand experiments have shown that 4 oz of cobalt sulphate per acre is sufficient as an annual topdressing to maintain the cobalt content of the pastures at a satisfactory level, thereby completely overcoming any danger from ailment.

Surveys of soils and pastures in different parts of New Zealand have resulted in a fairly accurate picture of the extent of cobalt deficiency in New Zealand, thereby enabling the results of the cobalt investigations to be applied with economy and certainty in all districts where difficulty is likely to be encountered.

Copper deficiency

Until recently no case of copper deficiency either in plants or animals had been recognized in New Zealand, but during the last two years the investigations of the Department of Agriculture have shown that 'peat scours' and unthriftiness of stock on certain peaty soils of the North Island are caused by a deficiency of copper. 'Peat scours' and cattle unthriftiness have long been known on the peaty soils of the Hauraki plains. The trouble is worst in the spring when the flush of green grass is at its height. Young stock, particularly yearlings, are more severely affected than mature animals. Production of butter fat and the raising of young stock are gravely affected and in the case of sheep, great difficulty is experienced in rearing lambs. Until recently the only remedy was the removal of young stock to other soils and the frequent replacement of the ewe flock. As a result of the beneficial effects noted from the use of bluestone nicotine drenches administered to stock for the control of internal parasites, the possibility that copper had beneficial properties apart from the control of internal parasites was examined. The investigations have shown not only that copper sulphate controls the incidence of 'peat scours' and unthriftiness of cattle, but the presence of an actual deficiency of copper in the soil, pasture and animal organs. The following figures were obtained by Dr I. J. Cunningham, in his investigations :

TABLE 3

COPPER CONTENT OF PASTURES AND LIVERS

normal pastures . . .	10 to 15 p.p.m. copper on dry matter
affected pastures . . .	2 to 5 p.p.m. copper on dry matter
livers of healthy cows . .	210 p.p.m. copper on dry basis
livers of affected cows . .	9·7 p.p.m. copper on dry basis
livers of healthy lambs . .	400 p.p.m. copper on dry basis
livers of affected lambs . .	16·2 p.p.m. copper on dry basis

The differences in copper content between healthy and affected specimens are even greater than those noted for cobalt deficiency. The field experiments have shown that bluestone used as a drench or in 'licks' or for topdressing pastures is highly beneficial and to a very great extent overcomes the difficulties which farmers have experienced.

The dose of bluestone recommended as a result of the investigations is 1/8 oz bluestone per week for adult cattle or 5 lb bluestone per acre for topdressing pastures. Pastures topdressed with bluestone at this rate have shown an increase in copper content of 100 to 200 per cent and have resulted in a 20 per cent increase in butter fat production and greatly increased returns from ewes both in lambs and wool.

BORON DEFICIENCY

Following on the discovery by Brandenburg in 1931 that 'crown-rot' of sugar beet and 'heart-rot' of root crops was caused by a deficiency of boron, New Zealand investigators showed in 1935 that a widespread ailment of apples in the Nelson district known as 'corkypit' or 'internal cork' was caused by a deficiency of boron. The extension of investigations to Central Otago revealed similar ailments of apples and stone fruits which were all controlled by the use of borax, either as a topdressing around the trees or as dilute sprays. The investigations have included detailed examinations of soils, leaves and fruit of apples, apricots, plums and grapes for boron and the effect of using borax in sprays and at different topdressing rates on the incidence of the ailment and on the quality of the fruit.

BORON STATUS OF FRUIT SOILS

Boron deficiency is restricted to fruit soils in the Nelson district and Central Otago, the fruit soils of Canterbury, Hawkes Bay and Auckland being relatively well supplied with this element.

Typical boron figures for representative soils in the Nelson district are as follows :

TABLE 4

BORON STATUS OF NELSON FRUIT SOILS

Stoke loam (healthy) . .	0–3″ 0·22 p.p.m. on dry soil 3–6″ 0·20 p.p.m. on dry soil
Moutere loam (affected) .	0–3″ 0·11 p.p.m. on dry soil 3–6″ 0·08 p.p.m. on dry soil
Kaiteriteri loam (affected) .	0–3″ 0·16 p.p.m. on dry soil 3–6″ 0·10 p.p.m. on dry soil

Note.—Boron extracted from the soils by N/20 HCl.

Boron status of fruit and leaves

The boron content of affected apples was found to be one quarter to one fifth of that present in healthy fruit, while the boron content of apple leaves on affected trees was about one half of that from healthy trees, as the following figures show :

TABLE 5

Boron status of apples and leaves

apples affected . .	3 to 5 p.p.m. boron
apples healthy . .	13 p.p.m. boron
leaves affected . .	9 to 11 p.p.m. boron
leaves healthy . .	17 to 18 p.p.m. boron

Control of boron deficiency

The investigations showed that ½ lb hydrated borax per tree, used as a topdressing, gave a complete control of the ailment for a period of at least four years. When used at higher rates than ½ lb per tree, borax had a detrimental effect on the cool storage quality of Jonathan apples and in certain cases even on the health of the trees. This was particularly true in the case of dressings exceeding 2 lb borax per tree.

Borax sprays of 0·5 and 0·1 per cent were also tested with good results. Complete control of 'internal cork' was secured with each strength and no damage to foliage or fruit accompanied the use of the borax sprays. Moreover it was found that at a dilution of 0·1 per cent borax could be introduced into the lime sulphur-lead arsenate sprays without loss of efficiency in the control of 'internal cork' or the appearance of detrimental effects from the combined spray. As a result of these investigations it was possible to recommend two sprays in November containing 0·1 per cent borax as an alternative to the use of ½ lb hydrated borax for topdressing around the trees.

'Brown spotting' of apricots, necrosis of plums, and grapes, responded to similar treatment as that used for boron deficiency in apples.

Brown heart of swedes and turnips

Investigations carried out by the Department of Agriculture and the Cawthron Institute showed that this trouble occurred rather extensively in different parts of New Zealand. The pumice soils of the central North Island territory, many soils in the Nelson district, Central Otago and Southland were found to be deficient in boron in respect to the requirements of these crops. The investigations showed the danger of mixing borax with the seed or introducing borax into superphosphate—usually drilled with the seed—on account of the detrimental effects on seed germination. The best result was obtained when borax at the rate of 20 lb per acre was drilled and harrowed into the soil prior to the sowing of the seed.

Chemical determinations of boron in swedes and turnips showed that roots affected with 'brown-heart' contained 4 to 6 p.p.m. boron on the dry matter, compared with 18 to 19 p.p.m. for healthy roots.

One of the interesting features of the boron investigations carried out in the Nelson district was the occurrence of boron deficiency of tobacco as a result of liming too heavily certain sandy soils which are commonly used for tobacco culture. Normally such soils do not exhibit symptoms of boron deficiency but with heavy lime treatment, boron is thrown out of the soil solution, thereby creating deficiency conditions of this element. In severe cases growth is arrested and the tobacco plants remain dwarfed throughout the season.

Magnesium deficiency

Two cases of magnesium deficiency in plants have been identified in New Zealand. In both cases deficiency of this element is associated with soils in the Nelson district. 'Sand-drown' or magnesium deficiency of tobacco occurs on sandy soils in the Motueka district, while magnesium deficiency of apples is widely distributed on soils derived from the Moutere Hills—an old alluvial formation which has been greatly leached of bases and plant foods. In the case of 'sand-drown,' mottling of leaves and deterioration in quality of leaf is common, while in severe cases the growth of the tobacco plants is affected and the upper leaves are small and narrow.

Investigations carried out in the Nelson district show that 'sand-drown' can be controlled by the use of 5 cwt of ground dolomite per acre. As magnesium is low in many soils used for tobacco culture, dolomite is now incorporated into the tobacco fertilizers in such a proportion as to give 80 lb dolomite per acre. This practice has resulted in improvement in the colour and quality of the tobacco leaf.

Magnesium deficiency of apples

During the course of certain long term manurial experiments carried out by the Cawthron Institute on the Moutere Hills, Nelson, it was noticed that the leaves of trees on plots which had received heavy dressings of potassic manures assumed a brown colour and dropped from the tree in mid summer, thereby limiting the growth of the apples and detrimentally affecting the quality of the fruit.

Injection experiments carried out with a number of salts showed that magnesium sulphate arrested the 'brown blotch' of the leaves and the subsequent early defoliation of the trees. Chemical analysis of the leaves showed in the case of affected trees a magnesium content of only one third of that present in healthy trees. The soils likewise contained only small amount of replaceable magnesia, usually less than 0·3 mg., equivalents per 100 grams of soil.

A survey of the orchards on the Moutere Hills showed that 'premature defoliation' was not confined to orchards where potassic manures had been used somewhat liberally for some years but was common, although not in such severe form, in many orchards where little, if any, potassic manures had been used.

Various magnesium compounds such as magnesium sulphate, magnesium carbonate, ground magnesite and ground dolomite, have been tested by officers of the Cawthron Institute with a view to overcoming magnesium deficiency. Magnesium sulphate and magnesium carbonate gave a more

immediate effect on the trees than ground magnesite and dolomite, but the beneficial effect of magnesium sulphate was of short duration owing to the rapid leaching of soluble magnesium salts from the soil.

Although not quite so quick in their effect, ground magnesite and particularly ground dolomite gave the most permanent results at considerably lower cost than was the case with magnesium sulphate and carbonate.

The experiments showed that a single application of ground dolomite at the rate of 12 lb per tree, or two successive applications at the rate of 6 lb per tree, gave a very satisfactory control of premature defoliation and very marked improvement in growth of the trees, yield and quality of fruit. A period of two years, after application of the dolomite, is required before the full effect of the magnesium application is observable in the foliage of the trees. In the case of orchards where very heavy applications of potassic manure had been made, a longer period is required before complete recovery of the trees is obtained. Leaves on the current season's leader growth were found most suitable for ascertaining the relative magnesium status of apple trees. The fourth and fifth leaves from the bottom of the leader were invariably lower in magnesium than other leaves. The magnesium content is slightly higher in leaves below the fourth on the leader and the content of magnesium increases very markedly towards the tip of the leader where differences in magnesium content between healthy and affected leaders are comparatively small.

Manganese deficiency

Only once case of manganese deficiency affecting the growth of cultivated plants has been noted, so far, in New Zealand. A mottling of leaves of citrus trees at Kerikeri, North Auckland, has been shown to be overcome by sprays of manganese salts. Chemical analyses of mottled leaves showed a relatively low status of manganese. The area affected by manganese deficiency is restricted and so far has not affected seriously either the growth of trees or the yield of fruit.

MODERN DEVELOPMENTS IN SOIL MECHANICS

By Dr P. O. Ripley

Historical background

In order to fix in our minds just what is involved in 'soil mechanics' it might be well to review briefly how this comparatively new branch of scientific inquiry has been developed :

Present knowledge of soils says Hogentogler (1) represents the composite results of effort made independently in different fields of endeavour to determine the manner in which this material originated and the properties that control its performance in agriculture, industry and engineering.

The geologist has contributed to this knowledge by a study of the formation of soil materials from parent rock and the distribution of these materials in various layers under the earth's surface.

The agronomist has studied the soil from the standpoint of crop production. Soil texture, moisture, structure, chemical constituents, have been studied in relation to drainage, irrigation, soil erosion and tilth.

Industrial chemists have investigated the soil in its relation to the manufacture of cement, glass, ceramic articles and other materials.

Highway and structural engineers have studied soil from the standpoint of its ability to support roadways, buildings, bridges, fills, dams, airport runways and as an aggregate in concrete, asphalt and stabilized soil mixtures.

Hogentogler (1) defines soil mechanics as that branch of science which deals with the performance of soil as a structural material. While soil mechanics as recently developed has come to be thought of more particularly from a structural material standpoint it has been developed basically, as shown above through soil physics studies in various fields of endeavour. It has been said that its origin dates back to 250 B.C. at which time Archimedes is credited with having established some of the principles of hydraulics. Other scientists like Galileo in 1630, Coulomb in 1773, Stokes in 1856 and many more have contributed basic information which have a bearing on this subject.

In 1892, Milton Whitney (2), then chief of the U.S. Weather Bureau and later chief of the U.S. Bureau of Soils, concluded that physical characteristics serve better than chemical analyses for indicating the performance of soils. He explained the effect of surface tension for contracting, expanding and supplying cohesion in soils ; suggested a formula expressing the relation between surface tension, diameter of capillaries and height of capillary rise ; and described a method for determining the moisture content of natural soils *in situ* by means of the changing electrical resistance between two installed metal plate terminals.

Since that time other individuals and agencies have developed various

theories which have been applied to the newer science of soil mechanics. These include theories and tests relating to

- size and shape of soil particles ;
- shrinkage of soil by surface tension when water recedes in soil capillaries ;
- plastic and shrinkage properties of soil (Atterberg test) ;
- bearing value of soils (roads, runways, etc.) ;
- consolidation tests ;
- compressibility, expansibility and permeability of soils ;
- soil drainage ;
- the occurrence and movement of ground waters ;
- soil stabilization. ;

Mathematical formulas have been made available for determining quantitatively the effects of surface tension and other phenomena on the performance of soils. Civil engineer societies and departments of highways have appointed committees and individuals to study the subject more thoroughly.

Keen (3) suggests that the credit for the first systematic study of the physical properties of soil belongs to Schubler of Leipzig who worked in the early nineteenth century. Translated into modern terms the properties he studied were as follows.

- Apparent and real specific gravity ;
- cohesion and plasticity ;
- shrinkage on drying ;
- moisture holding capacity ;
- rate of evaporation of water from soil ;
- rate of uptake of water vapour ;
- heat of wetting ;
- specific heat and thermal conductivity ;
- rate of absorption of heat radiation ;
- electrical conductivity.

Other soil scientists have added considerably to the knowledge of soil physics. These include Keen (3) of Rothamsted, mentioned above. One of the outstanding American soil physicists is Dr G. J. Bonyoucos of Michigan State College. Others include E. W. Hilgard of California Experiment Station, R. Bradfield of Cornell University, New York, and L. D. Baver of North Carolina State College.

The first official use of the term 'soil mechanics' in North America appears to have been in the title of the first International Conference on Soil Mechanics and Foundation Engineering held in 1936 at Cambridge, Mass., in connexion with the Graduate School of Engineering, Harvard University. (4) A large number of papers presented at this Conference covered the subject in a very comprehensive manner. Some of the general sections or topics discussed were :

- exploration of soil conditions and sampling operations ;
- regional soil studies for engineering purposes ;
- soil properties ;

stress distribution in soils ;
settlement of structures ;
stability of earth and foundation works and of natural slope ;
bearing capacity of piles ;
pile loading tests ;
earth pressure against retaining walls, excavation sheeting, tunnel linings, etc. ;
groundwater movement and seepage ;
soil problems in highway engineering, including frost action ;
methods for improving the physical properties of soils for engineering purposes ;
modern methods of design and construction foundations.

SOIL MECHANICS IN CANADA

To illustrate the interest in this science of 'soil mechanics' in Canada it might be mentioned that among the first courses to be given was one at the University of Alberta in 1932 on mechanics of granular materials, and instruction at the University of Toronto in 1936. A short course was presented by the Department of Civil Engineering at Toronto University in the spring of 1945 (5) and a refresher course in soil mechanics and concrete under the direction of the Department of Civil Engineering of the University of Alberta was held in January 1945 (6).

Among the topics discussed in connexion with these courses were the following :

Toronto University short course topics

Historical background of soil mechanics ;
geological aspects of soils ;
soil and agriculture ;
soil classification pedological classification, mechanical analyses soil types ;
soil moisture—significance and tests

(*a*) moisture content of soils,
(*b*) lower liquid limit,
(*c*) lower plastic limit,
(*d*) plasticity index,
(*e*) shrinkage limit,
(*f*) shrinkage ratio,

soil structure, soil stabilization and soil compaction ;
shear strength ;
stresses due to load ;
sub-surface exploration and field tests ;

University of Alberta topics

Some elementary principles of soil mechanics ;
soil sampling and testing ;
the mechanics of compaction and stabilization ;
frost action in soils ;

soil stabilization ;
soil-cement stabilization ;
foundations and wearing surfaces for flexible pavements ;
geology applied to dams and reservoirs ;
soil mechanics as applied to earth dams.

FIELDS OF INTEREST IN CANADA

Reference will herewith be made to a number of fields of interest which are effected by or which are interested in soil mechanics in Canada. These include :

the building trade, foundations, etc.
highway construction ;
runway construction, airports ;
dams, irrigation canals, etc.
harbour pier construction ;
soil mechanics and the design and operation of vehicles ;
agricultural interest in soil mechanics.

The building trade foundations

Comparatively little work has been done in Canada on the application of soil mechanics in any of the fields. Very little has been published regarding its application in the building trade. The soil formation is extremely important, however, in this connexion. The amount of clay or sand in the soil mass and the indirect effect of these materials on the moisture content, along with other physical factors indicate the pressure which the soil will bear in the way of structures built upon it and any settlement of the structure which may be anticipated. Effected also by soil type is the bearing capacity of piles.

Probably one of the most outstanding Canadian contributions with regard to foundation mechanics is that in connexion with construction in areas of permanently frozen ground. R. M. Hardy of the civil engineering staff of the University of Alberta and E. D'Appolonia of the department of civil and municipal engineering (7) of the same University have made a notable contribution in this regard. Hardy deals with the theory of frost action in soils. For soil to freeze implies that there is water in the voids between particles. In sands the water in the voids simply turns to ice on freezing causing only a small 5 per cent change in volume in saturated sand. In soils with silt or clay content however, ' ice lenses ' grow in the material. These are horizontal layers of solid ice varying in thickness from hair lines to a foot or more and in length from an inch to many feet. The growth of these ice lenses interspersed at regular intervals throughout the mass of soil may produce an increase of 200 per cent in the volume of the frozen soil. This increase in volume will produce a corresponding ' heave ' of any structure, highway or runway resting on the material. On thawing, these soils have a very high moisture content which produces a mucky mass incapable of supporting any type of building foundation.

In general clays are so impervious that they are seldom susceptible to serious frost action. At the other extreme clean gravels and sands are not susceptible to frost action because of their lack of fine particles. The

soils which give the most trouble are the silts and sandy silts with their relatively fine texture and high permeability permitting ice segregation to proceed at a relatively rapid rate. It is of considerable practical interest to note that a soil survey at sites subject to frost action and a few simple soil tests will enable dangerous soil types to be identified, will permit an intelligent analysis of the action of a foundation at the site and will facilitate the selection of the proper type of foundation.

In part 2 of his paper D'Appolonia deals with problems encountered with foundation structures and aircraft runways in the area of permanently frozen ground in these regions. The construction of the Alaska highway, large air ports and buildings associated therewith has provided an excellent opportunity to study related problems.

Failures which occur in frozen ground are mainly due to two fundamental causes.

(*a*) The thawing of the frozen ground which supports the structure,
(*b*) heaving which results from the growth of ice lenses in the soil.

Examples are given of a repeater station on the Alaskan Highway failing because of heat from the furnace thawing out the frost and resulting in a settlement of 7 inches. This was corrected by raising the building to allow a free airspace underneath. Supporting posts were sunk into the perma frost and provided with collars of tar paper and grease to prevent heaving. The floor was insulated to prevent heat transfer into the soil. Similar examples are given of a boiler house, warehouse, utility pipe lines for steam, water and sewer for a community.

General schemes for building foundations are described. Soil type determinations are important to a depth of 20 feet. A study of soil properties at all changes in stratum should precede building and important also is a study of the rate of heat transfer under a heated slab.

Piles are sunk into the perma frost to refusal after steam thawing and then refreezing sets them firmly in ten days to a week.

Information is also given concerning construction of hangars, highways and runways, road shoulders and culverts. The latter must be kept from freezing by steam thawing, small heated sheds at each end of the culvert or by large enough culverts to allow for a certain amount of freezing.

Highway and runway construction

Since many of the same principles apply to highway as to runway construction the two will be considered together. Compared with the United States the application of modern soil studies in highway work in Canada has been somewhat slow. A number of provincial highway departments now operate soil testing laboratories in connexion with their work. The Quebec Department of Highways has done considerable work in this regard. Piette (8) soils engineer of this Department, published a paper on 'Improved soil stabilization' with reference to highway construction in July 1944. In May 1945 Williams (9) of the Manitoba Department of Public Works published an article on application of soil mechanics to design and maintenance of prairie highways.

The war and the Commonwealth Air Training Plan have stimulated the construction of runways in Canada. Some attention has been focused on

soil mechanics in this field. Dr Norman McLeod of Imperial Oil Limited has made notable contributions with regard to road and runway construction. His study into the use of rapid curing bituminous material for waterproofing fine soil particles has been a special and quite successful means of soil stabilization. Soil cement has been used on a few important jobs in Canada and the use of calcium chloride is now common in many parts in connexion with the construction and maintenance of secondary roads where soil stabilization is used.

McLeod (10) emphasized the utility of agricultural soil maps to the highway and airport engineer. These soil maps provide a key to the nature of the drainage, subgrade, and other soil engineering problems to be expected in any locality and by showing the exact boundaries between the areas occupied by different soils indicate the exact location where the engineering treatments required for each soil should begin and end. More detailed information is usually required for roadway construction than is usually contained on agricultural soil maps, but the principles involved in the detailed survey are similar to those used in reconnaissance surveys.

Dr McLeod covers also in his various presentations :

(*a*) The fundamentals of soil drainage related to road construction (capillary moisture sub-drains, etc.).

(*b*) Principles of subgrade construction.
Consolidation of subgrade, relation of grade line to water table, elimination of subgrade frost heaving and frost boils by removal of silt pockets and back filling with gravel or other suitable soil material, subgrade construction through swamp areas.

(*c*) Fundamentals of base course design.
Soil stabilization, moisture content and compressive strength, influence of particle size on compressive strength, the effect of density, plasticity, shape of aggregate, etc.

(*d*) The importance of adequate field laboratory control.

(*e*) Wearing surfaces.

Dams, irrigation canals, etc.

Probably soil mechanics in Canada has been applied more in connexion with dams for irrigation, flood control, soil conservation and for irrigation canals than in any other field. This has been stimulated by the introduction of the P.F.R.A.* and interest in conservation measures. Soil mechanics tests have been used in connexion with a number of such projects.

The design and construction of the Shand Dam for the Grand River Conservation Commission in Southern Ontario (11) (12). This dam, 75 feet high, is built entirely of glacial till containing about half a million cubic yards of soil.

Considerable information has been obtained in relation to the Wild Horse Dam located on Sage Creek (13). This dam was a P.F.R.A. water conservation dam, 25 feet high, built of earth. It was completed in 1936 and because of inferior earth used in its construction it has washed out twice, once in 1937 and again in 1938. Correct soil mechanics information may have prevented this wash out.

* Prairie Farm Rehabilitation Administration.

Based on the experience with the Wild Horse Dam, extensive tests have been made before starting construction on the St Mary Dam, another P.F.R.A. project, on the St Mary River near Spring Coulee, Alberta (14) (15). This is to be an earth dam, 186 feet high, 300 feet long at the stream bed and 2,500 feet at the crest. Approximately $3\frac{1}{2}$ million cubic yards of soil will be used in its construction.

The nature of the soil and underlying bed-rock has been determined by borings made with a diamond drill. In the construction of earth dams it has been found necessary to build a core of relatively impervious clay. Such soil is readily eroded, however, and must be supported by a more gently sloping mass of more pervious material. Borings and examination of the soil for some miles around reveal the amount of soil of the various required types which is available for the construction of the different sections of the dam. The depth to bed-rock shows that facilities are available for obtaining foundation footings. For compaction of the soil in the earth dam a 'sheep's foot' roller has been devised, the spikes or projections on which are capable of exerting a pressure of from 500 to 1,200 pounds per square inch.

Harbour—pier construction

Although little use appears to have been made of soil mechanics as applied to harbour and pier construction it has been used to some extent. J. W. Lucas is in charge of a testing laboratory in the Department of Public Works, Ottawa, Canada. Tests are made in this laboratory pertaining to soil mechanics in relation to harbour construction. It is planned to extend this work.

Soil mechanics and the design and operation of vehicles

Arising from inquiries from the Canadian Army in connexion with the wartime operations of fighting vehicles an associate committee of the National Research Council on soil and snow mechanics was organized early in 1945. Studies have been made to date on interrelation of soil mechanics to the design and operation of track-laying vehicles. The Committee has observers on the Musk-Ox Expedition to the Canadian Arctic to study the 'muskeg' in the Arctic and also snow mechanics in relation to vehicles. Confidential reports have been published which include,

ground failure under the action of a track grouser ;
the interrelation of soil mechanics and the design and operation of vehicles ;
soil survey of vehicle proving establishment, Ottawa.

Agricultural interest in soil mechanics, P.F.R.A.

Reference has already been made to the application of soil mechanics in the construction of large earth dams, e.g., Wild Horse, St Mary Dam, etc. To the end of 1944 some \$47,000 has been spent on test borings on various projects in Saskatchewan and Alberta to determine foundation conditions for several proposed large dams.

PROJECTS UNDER P.F.R.A.

While actual tests may not have been made on all projects the principles of soil mechanics have been applied from a practical standpoint in connexion with many projects in the P.F.R.A. water development programme. To the end of 1944 these have included :

Large projects

Repairs to three large irrigation systems, e.g., Canada Land and Irrigation Company, Magrath Irrigation District, and Mountain View Irrigation District, to maintain a water supply to over 50,000 acres of irrigated land in existing projects.

Irrigation works have been improved in the Eastern Irrigation District involving the construction of two reservoirs to store 22,000 acre feet of water.

Creation of eighteen new irrigation projects covering when completed a total of approximately 110,000 acres of irrigated land and involving the construction of thirty-six dams to provide storage of some 365,000 acre feet of water.

Construction of thirty-seven stock-watering dams with a total capacity of some 15,000 acre feet.

Small projects

Water storage dugouts . . .	18,655
stock-watering dams . . .	4,178
irrigation projects	9,933

These have been constructed in the main on 23,826 individual farms.

In addition to these individual farm projects there have been the following small community projects.

Water storage dugouts . . .	189
stock-watering dams . . .	134
irrigation schemes	11

Such projects require the selection of sites where the soil is of the correct degree of permeability to retain the water and where the fill for earth dams is of the right texture to provide the most efficient retention of the water.

SOIL EROSION STUDIES AT SWIFT CURRENT, SASKATCHEWAN

Considerable work has been done in connexion with the application of soil physics and soil mechanics in relation to wind erosion of soils. A great deal of this work has been done at the Soil Research Laboratory at Swift Current, Saskatchewan. The following lines of investigation suggest the type of work being done at this laboratory :

The initiation of soil movement (by wind) study of specific gravity and size of individual grains and the effect of varying wind velocity.

The intensity of erosion as effected by wind velocity.

Cumulative intensity of drifting across eroding fields ; effect of air temperature on frictional eddies.

A rotary sieve method for determining the size distribution of soil clods.

The effect of humus and lime on soil drifting on various soil types.

The effect of water stable structure on cloddiness and erosiveness of soil.

The effect of puddling soils on soil drifting—effect on soil structure.

The effect of different cultural methods on soil drifting—the effect on soil structure.

Starting with a virgin soil how does cultivation change its physical properties.

The mechanics of soil drifting.

Dr J. L. Doughty sums up the work at Swift Current Laboratory as follows :

The physical properties of soil, which are considered in relation to any problem in soil mechanics, are also of particular importance in regard to soil erosion by wind. All soils are made up of particles of various sizes, which may or may not be aggregated into granules or clods. The relative proportions of the different sized particles and the tendency to form aggregates determines the susceptibility of soil to erosion.

Two wind tunnels have been used at the Soil Research Laboratory in the investigations pertaining to soil erosion by wind. One of these is situated in the laboratory and the other is portable for use in the field. The use of these machines has facilitated the study of erosion under more controlled conditions than prevail in the field. Winds of a uniform velocity can be produced and conditions repeated for subsequent experiments.

The studies to date have shown that an initial wind velocity of 11 to 13 miles per hour at one foot from the surface is required to start the movement of soil particles.

Soil particles from 0·05 to 0·5 mm. in diameter are the most susceptible to erosion by wind. Particles from 0·02 to 0·05 mm. and 0·5 to 1·0 mm. will move under higher wind velocities or when the wind is carrying particles of the more erosive size. Particles larger than 1·0 mm. in diameter are non-erosive or move only under extreme conditions.

Three types of movement are recognized in the transport of soil particles by the wind. The very fine particles are carried in suspension and after being lifted from the surface may travel many miles from the point of origin. Only a relatively small percentage of the total movement is carried in this manner. The major portion of the particles move down wind by a series of leaps or bounds, which is called saltation. The particles rise almost vertically into the air, gain momentum from the wind and return to the surface at a point some distance from the point of origin, depending on the wind velocity and the height of rise. On striking the surface they may rebound and continue the movement, kick other particles into the air or form part of the surface layer. The third type of movement is by surface creep in which the particles roll or slide along the surface due to the impact of the particles in saltation.

Approximately 90 per cent of the total movement is below a height of 1 foot and only a small percentage above a height of 38 inches.

Any surface obstruction, such as weeds, stubble, clods or ridges, which tends to reduce the wind velocity near the surface or to trap moving particles, reduces the susceptibility of the soil to damage by wind erosion.

The amount of material carried by a wind of given velocity tends to increase with distance from the windward edge of a field until a point is reached where the material falling to the surface is equal to that being removed. This distance may vary from 200 to 500 yards depending on the type of soil. The maximum rate of flow is attained in a shorter distance on sandy or granulated clay soils than on a medium textured soil. A clay soil that forms granules under the influence of weathering reacts very similarly to sand in regard to wind erosion. Loams or medium textured soils, that tend to form surface crusts and clods, are more resistant to erosion, but, after erosion has started, the abrasive action of the moving particles increase the amount of erosion material.

The effectiveness of the stubble strips in strip farming is due more to the trapping of the moving particles than to the reduction in wind velocity over the adjoining strip of fallow.

The erosiveness of a soil depends on the size distribution of the various particles and when this distribution is known, the erosiveness can be calculated. A rotary sieve has been developed for the separation of the particles. The machine consists of two sets of three concentric cylinders, part of each cylinder being a screen or sieve and the cylinder with the finest mesh screen being on the outside. The openings in the screens are as follows : 38·0, 12·7, 6·4, 2·0, 0·83 and 0·42 mm. The cylinders revolve around an axle set at an angle of 4° from the horizontal and rotate at a rate of 14 r.p.m. The gentle slope and slow rotation prevent undue abrasion during the passage of the soil through the cylinders. The use of this machine eliminates the personal element, which is so important in hand sieving.

The particles passing through the 0·42 mm. screen are the most erosive. The material passing through the 0·83 mm. sieve but not passing through the 0·42 mm. sieve is considered as erosive under more severe conditions. Larger sized particles are classed as non-erosive.

The rotary sieve would be equally valuable in determining the effect of tillage implements in pulverizing the soil when problems other than soil erosion were being studied.

Soil erosion studies at Scott, Saskatchewan

Moisture in the soil is an important factor related to soil erosion by wind. At the Scott Station intensive studies have been made in connexion with snow conservation and its effect on the moisture content of the soil (16). Snow fences, ridging, trash cover to hold the snow have increased the snow cover on certain areas and indirectly increased the moisture in the soil.

Screening the soil to measure the proportion of various sizes of soil aggregates under different methods of cultivation has given considerable information regarding the effect of cultivation on the erodibility of the soil (1938 report P.F.R.A. activities at the Scott Station).

Draft tests on various soil types

For several years before and after 1938 draft tests were conducted by the Swift Current Experiment Station on various implements on different soil types. Tests were made with double disc seed drills, single disc drills, one way disc, packers, duckfoot cultivators, spring tooth drags, disc harrow, rod weeders, cable weeders, blade weeders, mould board ploughs, disc ploughs and various combinations (tandem) of these implements, on different soil types under varying cropping and cultivation conditions. This type of work is very closely related to the vehicle test work by the committee of the National Research Council on testing army vehicles under differing soil conditions. In one case it is the effect on the traction vehicle itself the other on the implement being drawn by the tractor. Both should be considered. Similar draft tests on soil types have been conducted by Professor E. F. Hardy of the University of Saskatchewan.

Soil tillage

While soil mechanics may have come to be applied to engineering problems and tests there is no question that many of the principles on which soil mechanics is based are related to the field of soil tillage in connexion with which the Dominion Experimental Farm Service has for many years maintained an extensive programme of research work. This has been done in the regular experimental programme as well as in the cultural experiments under the P.F.R.A. Involved in such experiments are the following :

- Depth of ploughing experiments ;
- date of ploughing ;
- types of tillage implements, ploughs, blade weeders, rod weeders, one way disc, etc ;
- seed bed preparation ;
- summerfallow treatments ;
- trash cover ;
- the field of soil erosion (wind and water) control by cultural methods.

Water and soil erosion control structures

Considerable work and study has been given to water and soil erosion control structures by agricultural engineers at the Swift Current Station. T. S. Forsaith recently returned from overseas (1945) will be in charge of this work. Problems under study include :

- Seepage losses and lining in irrigation canals.
- Water control structures as regards seepage around and below the structure (culverts, spillways, chutes, dams, etc.).
- Silting and erosion. Silting reduces reservoir capacity, reduces irrigation canal capacity. Erosion results in the loss of good land, annoying gullies, washed out structures, canals and roads. Dykes in connexion with marshland reclamation are involved in this type of study. Soil mechanics studies may throw some light on these problems.

- The construction of asphalt lined spillways or rock lined chutes over earth dams or in drops in drainage ditches requires study. Asphalt spillways have suffered considerable damage by turning a head of water down before the asphalt had set.

Soil survey

Soil survey information as has been suggested already is used quite extensively in connexion with the application of soil mechanics studies. This might be summarized as follows :

- Soil type and water table information in relation to airport runway construction.
- Soil type and other data in relation to highway construction.
- Soil classification data related to earth dams, irrigation canals, drainage and irrigation systems.
- Soil classification related to tests of track laying and traction and transportation vehicles.
- Soil classification related to tillage implements, draft tests, abrasiveness of soils, power requirements, etc.
- Soil survey maps used in locating building sites. Location of sites for gasoline storage tanks at Suffield, Alberta, army testing grounds.

References

(1) Hogentogler, C. A. *Engineering Properties of Soil,* McGraw-Hill Company, Inc., New York and London, 1937.
(2) Whitney, Milton. Some physical properties of Soil in Their Relation to moisture and crop distribution. *U.S.D.A. Weather Bureau Bulletin,* **4,** 1892.
(3) Kenn, Bernard A. *The Physical Properties of the Soil.* Longmans Green and Co., London, New York, Toronto, 1931.
(4) *Proceedings of the International Conference on Soil Mechanics and Foundation Engineering,* **1, 2** *and* **3.** Harvard University, Cambridge, Mass., 1936.
(5) Fundamentals of Soil Mechanics, Summaries of lectures given in a Short Course arranged by University of Toronto. Roads and Bridges, 55, July 1945.
(6) *Report of the Proceedings of the First Refresher Course in Soil Mechanics and Concrete, University of Alberta,* Dept. of Extension, Univ. of Alberta, Edmonton, Alberta, January 1945.
(7) Hardy, R. M. and D'Appolonia, E. Permanently Frozen Ground and Foundation Design. *Engineering Journal,* Montreal, Canada, **29,** 24, January 1946.
(8) Piette, Grillaum. Improved Soil Stabilization. *Engineering Journal,* July 1944.
(9) Williams, G. B. Application of soil mechanics to design and maintenance of Prairie Highways. *Engineering Journal,* May 1945.

(10) McLeod, Norman W. *Soil Technology applied to Modern Highway and Airport construction.* Department of Asphalt Technology, Imperial Oil, Limited, Toronto, Ontario, 1941.
(11) McQueen, A. W. F. and McMordie, R. C. Soil Mechanics at the Shand Dam. *Engineering Journal*, Montreal, **23,** April 1940.
(12) Legget, R. F. An Engineering study of Glacial drift for an earth dam near Fergus, Ontario. *Economic Geology*, **37,** New Haven, November 1942.
(13) Peterson, R. Soil Mechanics as applied to earth dams. *Report of Proceedings of the First Refresher Course in Soil Mechanics and Concrete, University of Alberta*, Edmonton, Alberta, 1945.
(14) Peterson, R. Soil Mechanics as applied to P.F.R.A. Problems with special reference to the proposed St Mary Dam. *Engineering Journal*, Montreal, **28,** May 1945.
(15) Purser, Ralph. Engineers to the Rescue. *Family Herald and Weekly Star.* February 21, 1945.
(16) Matthews, G. D. *Snow Utilization in Prairie Agriculture, Publication* 696, Dominion Department of Agriculture, Dominion Experimental Station, Scott, Saskatchewan, May 1940.

GAME IN RELATION TO ANIMAL DISEASES

By Dr P. J. Du Toit, Onderstepoort, South Africa

'Game' has been defined as 'the various animals which are considered worthy of pursuit by sportsmen' (Webster).

In this definition I dislike the word 'game' and I object strongly to the use of the word 'sportsmen' for a class of person whose idea of 'sport' is the killing of defenceless animals. In this 'game' the dice seem to me to be unduly heavily loaded.

But in spite of this objection I shall, because of its general acceptance and its brevity, continue to use the word 'game' for the indigenous wild fauna, particularly the large mammals, of the various countries.

Africa is exceptionally rich in game. They represent an asset of great value, both for sentimental and for economic reasons; but they also represent a danger, as we shall see.

Other countries may well envy us our natural fauna. It is interesting to note that the United States, more than a dozen years ago, spent some 13 million dollars annually on her national parks and monuments. In these parks, covering about 19,500 square miles, they have, apart from bears, eight species of wild ruminants. We in South Africa, in our dozen parks, covering about 11,500 square miles, have lions, elephants, baboons, monkeys, giraffes, rhinoceroses, hippopotamuses, crocodiles, ostriches, leopards, cheetahs, hyenas, warthogs, bushpigs, zebras and some thirty species of ruminants, including the buffalo, eland, koodoo, wildebeest, hartebeest, gemsbuck, sable antelope, roan antelope, waterbuck, nyala, blesbuck, springbuck, impala, bontebuck, bushbuck and many more.

The great value of such a wonderful fauna to a country need not be stressed, and it is our duty to the world at large to preserve it for posterity. But our desire to preserve this asset dare not blind us to the dangers inherent in the preservation of the game.

In this discussion I shall confine myself to the danger of game becoming infected with, or being the carriers of, diseases transmissible to domestic animals.

The classical example of a disease fatal both to domestic animals and game is *rinderpest*. In its march through Africa in the 1890's this disease killed off large numbers of game, almost exterminating some species. The species which suffered most were buffalo, koodoo, waterbuck, reedbuck, warthog and bushpig. But also eland, sable, wildebeest, giraffe and many other species were found to be susceptible and suffered losses.

The most serious aspect of the problem is not so much the immediate mortality in game and cattle, disastrous though this may be, but rather the fact that the disease may persist in game and thus become endemic.

It was perhaps fortunate for us in South Africa that the disease was so virulent that it nearly wiped out some of the susceptible species of game, with the result that when the disease had passed through the country and

the cattle population had either died or been immunized, there was no focus of infection left. But Central Africa was not so fortunate. There the disease lingered on in cattle or in game and became endemic.

A strenuous campaign has been waged against rinderpest in both East and West Africa, since the end of last century. Millions of cattle have been immunized by various methods and, on the whole with very satisfactory results. Frequently the disease was suppressed completely in a certain area when, after a time, it broke out again. There is good reason to believe that in many of these recurrences game were responsible. Actually many outbreaks of rinderpest in game have been recorded, and frequently these were held responsible for outbreaks in cattle.

In the recent joint campaign undertaken by the Southern African states with the object of preventing the spread of rinderpest from Tanganyika towards the south, special attention had to be devoted to the game. The great danger was that infected game might migrate across the border from Tanganyika into Northern Rhodesia or Nyasaland and so start a conflagration in those countries. Accordingly elaborate precautions were taken on the border to prevent the crossing of game. A fence nearly 300 miles in length was erected and game were shot and driven away both north and south of the fence. In addition all cattle in the adjoining areas were immunized. A danger point that caused great concern was the border near the coast, between Tanganyika and Portuguese East Africa. In this wild country nothing could be done to control the game, but fortunately the disease did not spread there.

The measures adopted proved effective and rinderpest was kept out of the southern states. Had these steps not been taken a national catastrophe similar to that of 1896–1897 might have resulted.

In the case of *nagana* the rôle of game is perhaps even more serious. Ever since the classical investigations of David Bruce in Zululand in 1894 it has been known that wild animals may harbour in their blood the trypanosomes which cause fatal diseases in domestic animals and man. Generally these trypanosomes produce no clinical symptoms in the wild animals, but the *tsetse flies* which feed on these animals may pick up the infection and be able afterwards to transmit it to susceptible animals (or human beings).

These facts are not disputed. The only question that requires further discussion is in how far game must be held responsible for the outbreaks of nagana in cattle (or sleeping sickness in human beings).

The life of a tsetse fly is short, so that all infected flies would soon disappear unless new flies constantly picked up the infection from infected hosts. If infected cattle are present in a flybelt there is plenty of opportunity for the flies to become infected, but if cattle are completely absent the only possible source of infection is the game on which the flies feed. It follows therefore that if the game could be removed all infection must disappear.

But the ultimate object in any campaign against nagana is the complete eradication of the fly. One way of achieving this object would be to remove the food supply of the fly. Now it is known that tsetse flies live on blood only, so that it would only be necessary for this source of food to be removed for the flies to die.

This dual rôle of game, firstly as the carriers of the infection (trypanosomes) and secondly as the source of food for the transmitters (tsetse flies) of nagana, has prompted the idea that the game should be destroyed in or near flybelts where cattle are exposed to nagana infection. Such a suggestion immediately raises a storm of protest from game-protectionists and all animal lovers. But an involved matter like this can never be solved by relying entirely on sentiment or prejudice, just as little as it can be solved by ignoring completely the strong claims that can be put forward in favour of game preservation. Only by analysing calmly and dispassionately the facts that are available to us can we hope to arrive at a solution.

This matter was discussed fully at the Pan-African Conference held in Pretoria in 1929, when the following resolutions were adopted unanimously :

1. The preservation of all existing species of African mammals, with the exception of those directly dangerous to man, is both desirable and necessary.
2. The presence of game in settled areas, however, is a constant menace to stock, crops and general agricultural development. In this connexion special emphasis must be laid on the relation of game to such epizootic diseases as rinderpest, and their capacity for acting as hosts to many endo- and ecto-parasites of domestic animals.

   It is therefore uneconomical and unjustifiable to endeavour to enforce game preservation in such areas.
3. Adequate and efficiently controlled reserves should therefore be established away from settled areas.
4. Existing scientific evidence is now sufficient to justify the following conclusions :
   - (*a*) Game constitute the most important reservoir of the trypanosomes pathogenic to domestic animals.
   - (*b*) Game constitute the most important source of food to the open forest tsetse flies, such as *Glossina morsitans* and *G. pallidipes*.
   - (*c*) The disappearance of these species may be expected to follow radical reduction of all game animals in any area.
5. To ensure the perpetuity of game reserves and to prevent their constituting a menace to the surrounding districts, they should be free from *Glossinae*, with a reasonable prospect of so remaining.

It may be deduced from these resolutions that it was the considered opinion of this very representative Conference that game reduction was unavoidable if tsetse flies were to be eradicated. Experience in many parts of Africa has shown that no campaign against tsetse flies will be successful without adequate game reduction. Other methods such as bushclearing, veld burning, trapping, etc., may be very useful, but they will not achieve eradication of the fly if the game is left undisturbed. There is just a ray of hope that the new insecticides (D.D.T., etc.) will enable us in future to destroy the tsetse fly without destroying the game.

Another disease in which game play a part is *foot-and-mouth disease*.

It has been known for many years that some species of wild animals are susceptible to this disease. The most spectacular proof of this was furnished in 1924 when the disease broke out amongst the deer in the Stanislaus National Park in California and more than 22,000 animals had to be destroyed before the disease was eradicated.

In Southern Africa, too, in the outbreaks which occurred since 1931, the infection was found in game (buffalo, koodoo, sable, impala, etc.) on several occasions. In Southern Rhodesia it was proved that infected material taken from a koodoo, when transferred to cattle, produced the disease.

The important question is whether foot-and-mouth disease can linger on in game, in which it would produce only very mild, perhaps almost imperceptible symptoms, and then be responsible for a serious outbreak in cattle when they come in contact with the infected game. It is difficult to get positive proof of such an occurrence, but there is a very strong presumption that several recent outbreaks in cattle originated in game. Thus in 1940 the disease broke out in an isolated herd of cattle at Wankie in Southern Rhodesia. These animals were far removed from the next nearest herd of cattle, the country around the Wankie mine being infested by tsetse ; there are no cattle but plenty of game. The probability is that the herd at Wankie became infected from the game ; suspicious lesions were actually found in a koodoo and a buffalo in the neighbourhood. A similar outbreak occurred at Mamwala in Northern Rhodesia in 1944.

The outbreaks that occurred on the borders of the Kruger National Park towards the end of 1944 also gave rise to very strong suspicion that the infection came from the game in the Park. At those points where there was closest contact between cattle and game the disease first broke out.

A further disease which is transmitted from game to cattle is *malignant catarrh* (or '*snotsiekte*,' as it is sometimes called in South Africa). Here again wild animals, the blue and the black wildebeest (*Gorgon taurinus and Connochaetes gnou*) are latent carriers of the infection and show no symptoms at all. But when domestic cattle come in close contact with infected wildebeest the virus is transmitted and a fatal disease, which may spread through the herd, is set up in the cattle. It may be interesting to record one actual instance where a blue wildebeest cow died leaving a young calf behind. The calf was fed on a domestic cow foster-mother which contracted malignant catarrh and died. This was the start of a serious outbreak of the disease in a valuable herd.

In Europe it is believed by many that sheep form the reservoir of malignant catarrh of cattle. Preliminary experiments in South Africa have shown that sheep may also act as reservoirs here, but the chief culprit seems to be the wildebeest.

A very similar sequence of events is found in *swine fever* in South Africa. The natural carriers of the infection are wild pigs, both the warthog (*Phacochoerus aethiopicus*) and the bushpig (*Potamochoerus koiropotamus*). These animals show no symptoms of disease, but when they come in contact with domestic pigs they transmit the infection and cause a most fatal disease. This strain of swine fever virus is actually much more deadly than the European or American strain. The two strains are immunologically distinct.

This latent infection with swine fever seems to be widespread among the wild pigs in the Northern Transvaal and probably in other parts of Africa. The eradication of these animals is no easy matter, but fortunately it seems that very close contact between the wild and domestic pigs is necessary before the disease can be transmitted and by taking precautions this contact can, to a large extent, be prevented.

Rabies should be mentioned here, because in South Africa it is derived almost exclusively from wild animals. Several species of mungoose, belonging to the family *Viverridae*, two species of wild cat and a ground squirrel have been found infected in nature. In the case of rabies the wild carriers suffer just as much as the domestic animals and die from the disease. They infect each other in nature as well as domestic animals or human beings if these should be bitten by an infected specimen.

Attempts are made in badly infected areas to eradicate these small carnivores by gassing their burrows and by trapping ; but it is a very big undertaking. In localized areas complete eradication has been achieved.

A last example in this group of diseases may be mentioned. In the Kruger National Park it was observed by the late warden, Colonel Stevenson-Hamilton, that wild dogs (*Lycon pictus*), which at one time were plentiful, had practically disappeared. At the same time it was found that domestic dogs could not be kept in the Park, but invariably died after a time from some mysterious disease. The matter was investigated and it was found that the cause of the disease was a *Rickettsia* (*R. canis*) which was transmitted from dog to dog by a tick. The presumption is that the disease was originally brought to the Park by the wild dogs which infected the ticks and so caused the disease to appear in domestic dogs. Unfortunately, as was feared, the disease now seems to have spread to other parts of the country.

But not only protozoal and virus diseases, also ordinary *bacterial diseases* may appear in wild animals and may again be transmitted from them to domestic animals. Two examples may suffice.

In the Albany district, in the Eastern Cape Province of South Africa, it was found that koodoos were dying in considerable numbers under suspicious conditions. Investigation revealed that they were dying from *tuberculosis*. The surprising aspect of this outbreak was that these animals, which were always thought to be highly resistant to such diseases, and were living in an open, sundrenched country, should contract and die from tuberculosis.

The other example is *anthrax*. Most wild animals are just as suceptible to and die just as readily from anthrax as domestic animals when they are exposed to infection. However, it is possible that the disease may be present primarily in the wild animals and then be carried to domestic animals, as the following incidence shows. In the Kimberley district of the Cape Province a herd of hartebeest (*Bubalis caama*) has been preserved for many years on certain farms. During the last few years anthrax appeared in the herd and a number of these animals died. Recently the disease broke out among a valuable troop of horses on an adjoining farm and nearly 200 died. There is strong reason to believe that the hartebeest were responsible for the infection in the horses.

It is unnecessary, in this discussion, to refer to the many *ecto-* and *endo-*

parasites which are propagated on or in wild animals and may then be responsible for heavy losses among domestic stock. Enough has been said to prove that our wild fauna may be a serious menace to our domestic stock.

The question before us is how to reconcile the conflicting interests in this difficult problem. On the one hand we have the over-enthusiastic game-protectionists who claim that it is our sacred duty to preserve this wonderful heritage for posterity whatever the cost may be. At the other extreme we have many farmers and others who see in the game nothing but an obstacle to successful stockfarming and would like to see them completely wiped out. It is our duty as men of science to study the problem from all angles and point the way to the best solution.

The claim for game preservation must immediately be conceded. Every right-thinking and right-feeling person will admit that no effort should be spared to preserve, in perpetuity if possible, all those species of animals and plants which have survived the vicissitudes of evolution up to our own time. Few chapters in human history make sadder reading than those dealing with the disappearance of so many species of animals which became extinct within historic times. It is indeed gratifying to note that determined efforts are now being made in various countries to preserve those species which are still in danger of extinction.

But it is doubtful whether all so-called game-preservationists are actuated solely by these lofty motives. Many ' sportsmen ' want the game preserved so that they may shoot them at their leisure and so add to their collection of trophies. The greater the ' bag,' the better ' the day's sport.' It is against these hunters (not sportsmen) that the enthusiastic protagonists of game preservation should direct their energies, rather than against those who try to assist a sorely harassed farming community, by reducing the game in areas where game is a real danger. It would surprise many people to learn that the number of shooting licences issued in one shooting season in only a few districts of the Transvaal cover a much larger number of big game than the total number shot during the nagana campaign in Zululand during the last three years, and against which campaign there has at times been such an outcry.

It is not contended that there should be no shooting of game in areas where they are not responsible for major diseases amongst stock. Game must be controlled and reduced, if necessary, just as domestic stock; over-grazing and overstocking are no lesser evils when applied to game. But my contention is that too much unwarranted slaughter of game goes on under the guise of sport.

The disappearance of the game in many countries has been the almost inevitable result of advancing civilization. We must remember that so-called civilization is a brutal process. Examples readily come to mind of countries where the indigenous flora and fauna and, in some cases, even the original races of man disappeared soon after the outbreak of civilization. If we could protect our fauna against civilization their future would probably be assured.

If we ask the world at large to concede the claims for game preservation we must also ask the game-preservationists to concede the right and necessity for game reduction and, if need be, the total eradication of some

species where they constitute a meance to the human community and their livelihood. The examples quoted in the foregoing pages prove conclusively that game may be responsible for enormous losses and may even constitute a threat to the supply of human food. In such circumstances it is the duty of governments and particularly of the veterinary services of the countries concerned to take appropriate steps to avert the danger even though it may mean the destruction of game.

Much has been made of the cruelty of shooting game to protect the farmer and his stock. But, almost invariably, in cases where game destruction has to be carried out it is done by experienced marksmen under controlled conditions. The cruelty inflicted in such cases is infinitesimal compared with the cruelty of the veld, where lions and other carnivores kill numbers of terrified animals nightly ; or the cruelty of the abattoir ; or the cruelty due to those very diseases we try to control ; or the cruelty inflicted on those people whose only means of livelihood is taken from them by those diseases.

In conclusion, I would urge closer co-operation between those entrusted with the care and the preservation of game and those whose duty it is to look after the welfare of domestic animals (in regard to some problems the co-operation of the medical profession is also essential). At present we find instances of Boards of Management of Game Reserves which do not include a single scientific member. There seems to be a fear that such a member might bring to light some danger hidden in the reserve. But that is the policy of the ostrich. It would be far better to throw the full glare of scientific knowledge on the problem, to study carefully any danger there may be, and to try to devise means to counteract such dangers and so to ensure the safety and the future preservation of our wonderful fauna.

ARTHROPOD PESTS OF ANIMALS AND THEIR CONTROL IN THE UNION OF SOUTH AFRICA

By Mr R. Du Toit

The major problems which the owner of livestock in the Union is faced with so far as the external parasites are concerned may be summarized as follows:

First and foremost ticks of the family *Ixodidae*, which occur chiefly in the warmer and moister parts of the country but certain species of which are extremely troublesome in the western drier areas as well, constitute the major problem. Not only are they responsible for considerable economic loss by virtue of the direct effects of their bites and blood sucking habits, but also many diseases caused by protozoa responsible for heavy mortality are transmitted by them. Chief amongst these are East Coast Fever (Theileriasis), Heartwater (Ricketssiosis), Gallsickness (Anaplasmosis), Redwater (piroplasmosis) of cattle and Biliary Fever of horses and dogs. In the eastern coastal area of Cape Province and extending into Natal a strain of the blue tick, *Boophilus decoloratus*, which displays almost total immunity to arsenic, is causing grave concern both by virtue of the 'tick worry' caused by it and its capacity of transmitting Gallsickness and Redwater to cattle. Tick paralysis, caused by *Ixodes pilosus* and *Irubicundus*, in sheep in certain areas of the Cape Province constitutes a serious problem to sheep owners particularly in the winter months. The argasid tick, *Ornithodorous megnini*, is becoming increasingly prevalent in the drier areas of the country. The fowl tampan, *Argas persicus*, is widely distributed and spirochaetosis of poultry transmitted by it is fairly prevalent.

Next in importance to ticks the sheep blowflies are undoubtedly one of the greatest scourges the sheep farmer has to contend with. They are more or less ubiquitous in distribution but the problem assumes its greatest importance in the Karroo area or central portion of the Cape Province where the wool growing industry is chiefly centred. Closely allied to the sheep blowflies the cattle screw worm fly, *Chrysomyia bezziana*, which appears to have entered the Union from the north, is an increasingly serious pest to cattle ranch owners in the warmer bushed areas of the Transvaal and Natal.

Tsetse flies, the transmitters of the fatal Nagana or trypanosomiasis of many classes of stock are confined to the eastern portions of Zululand in Natal and make stock raising a hazardous undertaking in these parts.

Small night flying midges of the genus *Culicoides* have been shown to transmit the virus diseases Horsesickness of equines and Bluetongue of sheep, two highly fatal diseases of the utmost importance which are very widely distributed.

Keds (*Melophagus ovinus*) are responsible for considerable economic loss wherever woolled sheep occur except in the north-west sections of the Cape Province. The allied cattle fly, *Hippobosca rufipes*, is frequently a pest on

cattle and horses in the dry western sections of the Transvaal and Bechuanaland.

Amongst the dipterous parasites the horn fly, *Lyperosia minuta*, is of considerable importance to cattle owners in the coastal regions from Cape Aghullas to Zululand in Natal and extends even into the low-veld areas of the eastern Transvaal.

Lice, particularly of the sucking type, play an important part in the winter months particularly, throughout the country, the chief sufferers being cattle although goats are frequently severely affected.

Amongst the mites the sheep scab mite *Psoroptes communis* variety *ovis* is to-day relatively rare whereas occasional outbreaks of scab in cattle due to *Psoroptes natalensis* Hirst are met with. *Psoroptes communis* variety *caprae*, responsible for ear mange in goats is prevalent in the western portions of the Cape Province. *Dermanyssus gallinae*, the red mite of poultry, occurs sporadically from time to time. Demodectic mange in dogs has become fairly prevalent of late years but is of little importance in other animals. Sarcoptic mange is widespread and occasional cases of ear mange due to *Otodectes Cynotis* in cats are met with as well as rare cases of notoedric mange in these animals. A few outbreaks of foot mange in goats caused by *Chorioptes caprae* have been recorded.

Flies of the genus *Stomoxys* are widely distributed and have been responsible for considerable losses in new born lambs in the south western Cape Province in the late summer months due to their, presumably, spreading a fungoid skin disease known as lumpy wool (Dermatonomus sp.). Latterly they have been suspected of playing a part in disseminating mechanically the recently introduced Lumpy Skin Disease of cattle, a disease caused by a virus.

Control and remedial measures

Arsenical solutions comprising sodium arsenite are used generally as dips for the control of ticks on cattle, supplemented by hand-dressing with mixtures containing nicotine, pyrethrum, coal and fine tar derivatives, etc. In the case of sheep arsenical foot baths are generally employed. Other dipping materials used comprise lime-sulphur combinations for the control of mite infections in sheep and cattle and the so-called double dipping powders, trisodium-di-thio-arsenate, are popular. Arsenic-sulphur linkages are widely used for the control of lice on sheep and in combination with rotenone have been found to be particularly effective for the control of sheep keds.

Lice on cattle are successfully controlled by the addition of rotenone to arsenical dips. The control of the arsenic resistant blue tick can be successfully accomplished by the addition of nicotine to the ordinary arsenical dip, either as the sulphate or by cold extraction of waste tobacco in the tank. Shortages of nicotine during the war years have prevented the general application of this method however, and the tick has spread alarmingly as a consequence.

Recent experimental work on D.D.T. has indicated that this potent insecticide can be used successfully to protect sheep against the sheep blowflies for very considerable periods and a great measure of success has

attended its use in combatting horn flies on cattle. Emulsion sprays containing D.D.T. have been successfully employed against ticks of the family *Ixodidae* but the argasids display a high degree of resistance to it. Results obtained with the spraying of D.D.T. solutions from aircraft over bushed areas infested with tsetse flies have yielded fairly promising results to date but the work is still in the experimental stages and no definite conclusions can be arrived at yet.

Preliminary work with the gamma isomer of benzene hexachloride or '666' has indicated that distinct possibilities exist for its successful application against ticks and blowflies and experimental work is under way at present to determine its possible use as a dipping medium.

MICROBIOLOGY IN NEW ZEALAND

By Dr T. R. Vernon

(Microbiologist, Department of Scientific and Industrial Research)

Introduction

Until recently microbiology, as such, has not formed part of New Zealand's scientific effort. In the past, the microbiological work that has been carried out has been in the nature of specialized bacteriology or mycology applied to particular problems in particular industries. Medical, veterinary and dairy bacteriologists have practised in their respective fields, while mycology has been the province of the plant pathologist. Generally the emphasis has been on the parasite and pathogen rather than the saprophyte. This policy has no doubt served well in the past, but the growing importance of general microbiology, both from the fundamental and practical points of view, has shown it to be inadequate for present conditions.

New Zealand has a large exportable surplus of primary produce and its local secondary industries necessitated by its isolated position, place demands on its scientific services out of all proportion to its population. The need for general microbiological work suited to local needs is apparent and this gap in the scientific plan is now being bridged.

Antibiotics

A small organization consisting of a research unit and a pilot plant has been set up for work in antibiotics. The intense research activity that followed the development of penicillin has led to full appreciation of the great possibilities in this field of research. Although interest has been primarily concentrated on antibiotics effective against human disease, the scope of the work has now been extended to include both plant and animal pathogens and the study of the fundamental phenomenon of microbial antagonism in relation to soil microbiology and fertility as well as natural and industrial fermentations.

New Zealand's participation in antibiotic work is based on this broad general view. As a primary producing country stress is naturally being placed on the possibilities of antibiotics in relation to animal and plant diseases, but its policy must take into account every angle of antibiotic research of possible value to New Zealand.

The programme of work in antibiotics is divided into two parts (*a*) research and routine laboratory work, and (*b*) pilot plant production. On the research side it is clear that New Zealand's effort cannot be great, but it can perform a useful service and by investigating indigenous flora for new antibiotic substances may contribute something of value to the general pool of scientific knowledge.

Its main objectives are :

(*a*) To hold a watching brief on world research in antibiotics so that new knowledge and new discoveries of local application can be made use of with the least possible delay.

(b) To carry out laboratory fermentations and produce antibiotics which, although they may have been discarded as chemotherapeutants for human use, may yet be useful against animal or plant infections.

(c) To provide an assay and testing service for these and for such new antibiotics as may be discovered, using as test organisms human, animal and plant pathogens.

(d) To conduct a systematic search for new antibiotics from indigenous micro and macro flora. New Zealand's geographical isolation has given her a remarkable flora which it is not unreasonable to expect, together with peculiar climatic conditions, have produced local strains and varieties that may yield new antibiotics.

(e) The pilot plant is equipped for deep, surface and shake culture. It is a versatile unit both for production and extraction and is designed to produce penicillin or other antibiotics so that they may be supplied to user organizations such as the animal, plant or medical research units in sufficient quantities for sound experimental work. Full co-operation with these organizations is an essential part of the scheme. The necessity for team work is fully realized, but clearly a complete team on antibiotic work would not be justified in so small a country as New Zealand. It is believed, however, that with the co-operation of the existing research organizations there will be, in effect, not an isolated group working on antibiotics, but a complete team. Equally if not more important is the friendly association with workers overseas engaged in similar work.

General microbiology

The type of microbiological work required is governed by local conditions. Much of it will be in the nature of servicing local industries and translating overseas results to meet local conditions and requirements, but certain long term fundamental work may be justified.

Industrial spoilage through the action of micro-organisms is considerable. The processing, transport and storage of perishable goods in a sparsely populated country consisting of two long and narrow islands, with a wide range of climatic conditions frequently involving high humidities, present many spoilage problems. Apart from the primary industries, the local industries are too small and scattered to have their own research organizations, and microbiological servicing can only be carried out successfully by a government department. From every angle, health, economy and efficiency, such a service will pay handsome dividends.

At present the major industries, e.g. butter, cheese, fruit, etc., are well catered for by their own research stations. Wool and leather have special research organizations, but do little microbiological work, while the meat industry relies on overseas research entirely. It is the smaller industries, local foodstuffs, canning, curing, etc., that require some general microbiological service. There are also certain local problems in areas of high humidity such as the deterioration of paint instruments, building materials, etc.

Apart from cheesemaking, New Zealand is interested in four types of industrial fermentation. Brewing, wine making, retting and silage making. The complexities of natural fermentations really demand long term work which would not be justified, but some microbiological work relating overseas work and methods to local conditions would be of great value.

New Zealand's prosperity is based in the soil. The microbiology of the soil is no doubt fraught with difficulties, but difficulties are not overcome by avoiding them. New Zealand possesses certain advantages for the study of soil microbiology—virgin land untouched by man lies adjacent to cultivated soils—and a long term policy might well yield results of value.

In general microbiology has been neglected in the past by both the university and the research stations. The establishment of a unit for research in antibiotics with special reference to animal and plant diseases, is an important step towards making good this deficiency. More microbiological work, however, is still required, particularly for servicing the smaller industries and relating overseas research to local problems.

CALENDAR OF THE CONFERENCE

MONDAY 17 JUNE IN LONDON

10.30 a.m.	FORMAL OPENING by H.M. The King.	Place — William Beveridge Hall, Senate House, University of London, Malet Street.
1.00 p.m.	LUNCH	Place — Macmillan Hall, Senate House, University of London.
2.00 p.m.	DISCUSSION	United Kingdom contribution on general scientific organization. Place — William Beveridge Hall, Senate House, University of London.
5.30 – 7.00 p.m.	RECEPTION for	Indian delegates given by The High Commissioner for India. Place — India House, Aldwych.

TUESDAY 18 JUNE IN LONDON

10.00 a.m.	DISCUSSION	General scientific organization in Canada, New Zealand and the Colonial Empire. Place — The Royal Society.
4.45 p.m.	TEA given by the	Parliamentary and Scientific Committee. Place — Houses of Parliament.
8.00 – 11.00 p.m. approximately	FILM	'Science in Australia.' Place — The Royal Society.

WEDNESDAY 19 JUNE IN LONDON

10.00 a.m.	DISCUSSION	General scientific organization in Australia, South Africa and India. Place — The Royal Society.
1.00 p.m.	BUFFET LUNCH	Place — The Royal Society.
2.00 p.m.	Leave by coach for the	National Physical Laboratory.
2.45 p.m.	RECEPTION, VISIT and TEA.	Place—National Physical Laboratory, Teddington.

WEDNESDAY 19 JUNE IN LONDON (continued)

5.45 p.m.	Leave by coach for Lancaster House.	
6.30 p.m.	COCKTAIL PARTY, given by the Government.	Place — Lancaster House.

THURSDAY 20 JUNE IN LONDON

10.00 a.m.	DISCUSSION	Subject (f); methods of improving interchange of scientists, and the future of scientific liaison offices. Place — The Royal Society.
3.45 p.m.	TEA	Place — The Royal Society.
4.30 p.m.	LECTURE	Ordinary meeting of the Royal Society, during which Dr Wilder Penfield, F.R.S., the Director of the Montreal Neurological Institute, will deliver the Royal Society Ferrier Lecture on 'Some observations on cerebral cortex of man.' Place — The Royal Society.

FRIDAY 21 JUNE IN LONDON

10.00 a.m.	DISCUSSION	Subject (m); post-war needs of fundamental research. Place — The Royal Society.
1.00 p.m.	LUNCH for delegates who are chemists given by	the Chemical Society. Place — Stewart's Restaurant, Bond Street.
1.30 p.m.	LUNCH given by the Burmah Oil Company to	delegates from India and Burma. Place — Claridge's Hotel, Brook Street.
4.30 p.m.	RECEPTION and TEA, given by the English	Speaking Union. Place — Dartmouth House, 37 Charles Street, London.

FRIDAY 21 JUNE IN LONDON (continued)

7.00 p.m.	DINNER	For delegates who are members of professional Chemical Institutes in the Dominions : Meeting with the Officers of the Royal Institute of Chemistry, dinner at the Tallow Chandlers. Hall, 4 Dowgate Hill, E.C.4.

SATURDAY 22 JUNE IN LONDON AND IN CAMBRIDGE

10.00 a.m.	DISCUSSION	Subject (l) ; natural products of the Empire and chemical industries that are or might be based on them. Place — The Royal Society.
2.30 p.m.	Leave by coach for Cambridge from The Royal Society.	
5.00 p.m. approximately	Delegates arrive at Colleges, where they will have dinner at 7.00 p.m.	
9.00 p.m.	TALK on Cambridge and its history by Mr G. F. Hickson. Place — Arts School.	

SUNDAY 23 JUNE IN CAMBRIDGE

No arrangements.

MONDAY 24 JUNE IN CAMBRIDGE

9.30 a.m.	DISCUSSIONS	Subject (a) ; problems of agriculture. Place — Arts School. or—Subject (k) ; need for a co-ordinated survey of the mineral resources of the Empire. Place — Cavendish Laboratory Colloquium.
2.30 – 4.45 p.m.	DEPARTMENTS OPEN FOR VISITS	(i) Cavendish Laboratory, Free School Lane. Representative Mr I. T. James. Tel. 4765.

(ii) (a) Biochemistry Laboratory, Tennis Court Road.
Representative Prof. A. C. Chibnall, F.R.S.
Tel. 4361.

or

(b) Molteno Institute (Cellular Physiology), Downing Street.
Representative Dr E. F. Hartree.
Tel. 4577.

or

(c) Low Temperature Research Station, Downing Street.
Representative Dr E. H. Callow.
Tel. 4477.

5.00 p.m. CONFERMENT OF HONORARY DEGREES
Place — Senate House.

6.00 – 7.15 p.m. SHERRY PARTY, given by the Vice-Chancellor of the University of Cambridge.
Place — Clare College.

8.30 p.m. INFORMAL DISCUSSIONS

(a) Blood Groups — Mr R. Race.
Place — Pathological Laboratory.

(b) Geophysics in South Africa.
Prof. B. F. J. Schonland, F.R.S.
Place — Clare College.

(c) The role of minor elements in nutrition of plants and animals.
Mr H. R. Marston.
Place — to be settled.

TUESDAY 25 JUNE IN CAMBRIDGE

9.30 a.m. DISCUSSIONS Subject (h) ; greater uniformity in standards of measurement.
Place — Cavendish Laboratory Colloquium.

or—Subject (i) ; collection of scientific records and material and risks involved in the distribution of plants, seeds and animals.
Place — Arts School.

Notes : Departments grouped in square brackets are geographically close, so that more than one can be visited in the same afternoon. TRANSPORT WILL PICK UP AT CORNER OF DOWNING STREET AND FREE SCHOOL LANE.

2.15 – 5.00 p.m. DEMONSTRATION

(i) 2.15 – 3.30 p.m.	University Farm, Madingley Road. Representative Mr R. Ede. Tel. 2485. (A tour which begins with the University Farm and after tea divides into alternatives X and Y.)
3.30 – 4.00 p.m.	Tea.
4.00 – 5.00 p.m.	X—Plant Breeding, Potato Virus, Horticultural Research Station Empire Potato Collection. or Y—Animal Research Station. (Both X and Y are in Huntingdon Road.)

DEPARTMENTS OPEN FOR VISITS

(Tea will be served during the afternoon.)

(ii) 2.30 – 5.00 p.m.	Joint Visit. Department of Mineralogy, Downing Street. Representative Dr N. F. M. Henry. Tel. 3193. and Department of Geology, Downing Street. Representative Dr O. M. Bulman. F.R.S. Tel. 4192.
(iii) 2.30 – 5.00 p.m.	Department of Engineering, Trumpington Street. Representative Dr E. B. Moullin. Tel. 4495.

8.30 p.m. INFORMAL DISCUSSION

(a) Cosmic rays. Prof. H. J. Bhabha, F.R.S. Place — to be arranged.

Notes: Departments grouped in square brackets are geographically close, so that more than one can be visited in the same afternoon. TRANSPORT WILL PICK UP AT CORNER OF DOWNING STREET AND FREE SCHOOL LANE.

TUESDAY 25 JUNE IN CAMBRIDGE (continued)

(b) Soil mechanics.
Place and opener to be arranged.

(c) Physical properties of viruses.
Dr P. J. du Toit.
Place — to be arranged.

(d) Pentoxylydae, a new Jurassic gymnosperm from Behar.
Prof. B. Sahni, F.R.S.
Place — to be arranged.

WEDNESDAY 26 JUNE IN CAMBRIDGE

9.30 a.m. VISIT to Ely Cathedral.

1.00 p.m. Return to Cambridge.

4.00 – 6.00 p.m. GARDEN PARTY, given by St John's College.
Place — St John's College.

8.30 p.m. INFORMAL DISCUSSIONS

(a) The role of the village pond in the rural economy of India.
Dr S. L. Hora.
Place — to be arranged.

(b) Generation of high energy particles.
Prof. J. D. Cockcroft, F.R.S.
Place — St John's College.

(c) Extra-terrestrial radio waves.
Prof. F. J. M. Stratton.
Place — Gonville and Caius College.

THURSDAY 27 JUNE IN CAMBRIDGE

9.30 a.m. DISCUSSION Subject (e), scientific information services.
Place — Arts School.

2.30 – 5.30 p.m. DEMONSTRATIONS

(Tea will be served during the afternoon.)

(i) 2.30 – 4.00 p.m. Pest Control Ltd., Harston.
Representative Dr W. E. Ripper.
Tel. Harston 312.
(Demonstration of agricultural spraying by ground machines and aircraft.)

or (ii) 2.30 – 4.30 p.m. — Unit of Animal Physiology, Department of Physiology, Rooms, 28 and 29 Downing Street.
Representative Sir Joseph Barcroft, F.R.S.
Tel. 3844.
(Films on activity in foetal life (man and sheep). Recent advances in knowledge of ruminant digestion.)

(iii) 4.30 – 5.30 p.m. — Pye Radio Ltd., Haig Road, Chesterton.
Representative Mr Edwards.
Tel. 3434.
(Demonstration of Television.)

DEPARTMENTS OPEN FOR VISITS

(iv) 2.30 – 4.30 p.m.

[
(a) Chemical Laboratory.
Representative Dr F. B. Kipping.
Tel. 5075,

or

(b) Laboratory of Physical Chemistry.
Representative Dr F. P. Bowden.
Tel. 5075,

or

(c) Laboratory of Colloid Sciences.
Representative Dr A. E. Alexander.
Tel. 5075.

All these are in Free School Lane. Visitors to these three laboratories are asked to call at the Perse Room, at the Laboratory of Physical Chemistry first. Tea will be served in the Perse Room at 4 – 4.30 p.m.
]

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(v) 2.30 – 4.30 p.m.

(a) Department of Pathology. Representative Prof. H. R. Dean. Tel. 2232,

or

(b) Department of Experimental Medicine. Representative Dr R. A. McCance. Tel. 2389.

(c) Department of Medicine. Representative Sir Lionel Whitby. Tel. 2389.

All these are in the same building in Tennis Court Road.

8.30 p.m. INFORMAL DISCUSSIONS

(a) Oceanic Geography.
Dr E. C. Bullard, F.R.S.
Place — Clare College.

(b) The use of Tracer Elements and arrangements for their supply.
Prof. J. B. Collip, F.R.S.
Place — to be arranged.

(c) Constitution in cattle and its relation to pests and diseases.
Dr J. Hammond, F.R.S.
Place — Downing College.

FRIDAY 28 JUNE IN CAMBRIDGE

9.30 a.m. DISCUSSION Subject (b.ii), The etiology and control of infectious and transmissible diseases.
Place — Arts School.

2.30 – 5.00 p.m. DEMONSTRATIONS

(Tea will be served during the afternoon.)

(i) Cambridge Instrument Company, Chesterton Road.
Representative Dr A. E. Stone.
Tel. 4415.

Notes : Departments grouped in square brackets are geographically close, so that more than one can be visited in the same afternoon. TRANSPORT WILL PICK UP AT CORNER OF DOWNING STREET AND FREE SCHOOL LANE.

DEPARTMENTS OPEN FOR VISITS

(ii)
(a) Department of Zoology, Downing Street. Representative Prof. J. Gray, F.R.S. Tel. 2708,
or
(b) Department of Botany, Downing Street. Representative Prof. F. T. Brooks, F.R.S. Tel. 5113,
or
(c) Department of Agriculture, Tennis Court Road. Representative Mr R. Ede. Tel. 2485.

(iii)
(a) Nutritional Laboratory, Milton Road. Representative Dr Harris. Tel. 55444,
or
(b) Animal Pathology Laboratory, Milton Road. Representative Dr McGaughey. Tel. 5067.

8.30 p.m. CIVIC RECEPTION by the Mayor of Cambridge
Place — Guildhall.

VISITS

Visits to the following may be made in the afternoons of 24 – 28 June by arrangement either through the Information Bureau or direct with the respective representative :

Cambridge University Press, Trumpington Street. (At 2.30 p.m. on 27 or 28 June only.) Representative Mr Brooke Crutchley. Tel. 4226.

Strangeways Research Laboratory, Hills Road. (Demonstration and films any afternoon except Monday 24 June.) Representative Dr H. B. Fell. Tel. 87583.

Department of Metallurgy, Chemical Laboratory, Free School Lane. Representative Prof. G. W. Austin. Tel. 5075.

Notes : Departments grouped in square brackets are geographically close, so that more than one can be visited in the same afternoon. TRANSPORT WILL PICK UP AT CORNER OF DOWNING STREET AND FREE SCHOOL LANE.

Department of Mathematics, Free School Lane.
Representative Dr M. V. Wilkes. Tel. 5174.

Joint visit

Department of Geography, Downing Place.
Representative Mr W. W. Williams. Tel. 3809.
and
The Scott Polar Institute, Downing Place.
Representative Dr B. B. Roberts. Tel. 2983.

Laboratory of the Physics and Chemistry of rubbing solids, Free School Lane.
Representative Dr D. Tabor. Tel. 56346.

Department of Geophysics and Geodesy, Madingley Road.
Representative Dr E. C. Bullard, F.R.S. Tel. 56827.

Observatory and Solar Physics, Madingley Road.
Representative Prof. F. J. M. Stratton. Tel. 2413.

Entomological Field Station, Storey's Way.
Representative Dr V. B. Wigglesworth, F.R.S. Tel. 2536.

Department of Genetics, Storey's Way.
Representative Dr T. C. Carter. Tel. 55822.

Botany School Field Station, Storey's Way (adjoining the University Farm).
Representative Prof. F. T. Brooks, F.R.S. Tel. 5113.

Radiotherapeutics Laboratory, 'Kenmare,' Trumpington Street.
Representative Prof. J. S. Mitchell.

Department of Anatomy, Downing Street.
Representative Prof. H. A. Harris. Tel. 3289.

Department of Physiology, Downing Street.
Representative Prof. E. D. Adrian, F.R.S. Tel. 3844.

Department of Psychology, Downing Place.
Representative Dr N. H. Mackworth. Tel. 5101.

Note: TRANSPORT WILL PICK UP AT CORNER OF DOWNING STREET.

SATURDAY 29 JUNE IN CAMBRIDGE AND IN OXFORD

9.30 a.m.	Leave Cambridge by coach.	
2.00 p.m. (approximately)	Arrive in Oxford.	Delegates will be met by guides and taken to Colleges.
3.30 p.m.	INTRODUCTORY TALK by Sir Henry Tizard, F.R.S.	Place — Hall of Magdalen College.
4.30 p.m.	GARDEN PARTY	Place — Wadham College.
8.30 p.m.	RECEPTION, Vice-Chancellor of the University of Oxford will welcome the delegates.	Place — Rhodes House.

SUNDAY 30 JUNE IN OXFORD

10.00 a.m.– 5.00 p.m. (approximately)	EXCURSION	Itinerary to be arranged. Tea at Blenheim Palace.

MONDAY 1 JULY IN OXFORD

9.30 a.m.	DISCUSSIONS	Subject (b.i) ; problems of medical science, including a discussion of the physiological and psychological factors affecting human life under tropical conditions and in industry. Place—Bio-chemistry Lecture Room.
	or	Subject (d) ; modern methods of mapping and exploration by air, including use of radio technique. Place — Physical Chemistry Lecture Room.
2.00 p.m.	CONFERMENT OF HONORARY DEGREES	Place — Sheldonian Theatre.
2.45 – 5.00 p.m.	VISITS AND DEMONSTRATIONS	(i) Informal discussion on Atomic Energy — Clarendon Laboratory. Lord Cherwell, F.R.S.
	or 2.15 p.m.	(ii) Department of Agriculture—with excursion to Long Wittenham or Wilcot. Dr G. E. Blackman.

MONDAY 1 JULY IN OXFORD (continued)

or (iii) Visit to Wingfield—Morris Orthopaedic Hospital.
Professor H. J. Seddon.

5.30 p.m. COCKTAIL PARTY, given by the Nuffield Foundation.
Place — Christ Church Hall.

8.30 p.m. INFORMAL DISCUSSIONS

(a) Recent advances in Chemotherapy.
Dr F. E. King and Dr J. Walker.
Place — Dyson Perrins Laboratory.

(b) Long-range weather forecasting.
Prof. S. Chapman, F.R.S., Prof. G. M. B. Dobson, F.R.S., and Dr A. H. R. Goldie.
Place — School of Geography.

(c) Economic Ornithology and bird population problems.
Mr W. B. Alexander and Mr D. Lack.
Place — Edward Grey Institute.

TUESDAY 2 JULY IN OXFORD

9.30 a.m. DISCUSSION Subject (n); Co-ordination of scientific work within Africa.
Place — Physical Chemistry Lecture Room.

2.15 – 5.00 p.m. VISITS AND DEMONSTRATIONS

(i) Air Survey at Benson and Nuneham A.O.C. 106 Group R.A.F.

(ii) Botanical Gardens.
Dr T. G. B. Osborn.

(iii) Cineradiography — Nuffield Institute for Medical Research, Woodstock Road, Oxford.
Mr A. E. Barclay.

8.30 p.m. INFORMAL DISCUSSION

(a) Recent advances in pharmacology.
Prof. J. H. Burn, F.R.S., and Dr C. H. Kellaway, F.R.S.—Pharmacology Laboratory.

(b) Present position in Cosmology. Prof. E. A. Milne, F.R.S.—Hertford College.

(c) Collaborative research in anthropology. Prof. W. E. Le Gros Clark, F.R.S., and Mr M. Fortes. Place — Exeter College.

WEDNESDAY 3 JULY IN OXFORD

9.30 a.m. DISCUSSION Subject (c) ; Nutrition. Place — Physical Chemistry Lecture Room.

2.15 – 4.15 p.m. VISITS AND DEMONSTRATIONS

(i) Meteorology of the upper atmosphere, Clarendon Laboratory. Prof. G. M. B. Dobson, F.R.S.

(ii) Department of Forestry and Imperial Forestry Institute at School of Forestry. Dr H. G. Champion.

(iii) Institute of Social Medicine. Dr J. A. Ryle.

4.30 p.m. RECEPTION and TEA, given by the Mayor of Oxford. Place — Guildhall.

8.30 p.m. INFORMAL DISCUSSIONS

(a) Recent developments and applications of infra-red work in chemistry and physics. Dr H. W. Thompson, F.R.S.—Physical Chemistry Laboratory.

(b) Hormones. Prof. J. B. Collip, F.R.S. Place — to be arranged.

THURSDAY 4 JULY IN OXFORD

8.30 a.m. – 8.30 p.m. (approximately) VISIT to Telecommunications Research Establishment in Great Malvern. Dr W. B. Lewis, F.R.S. Lunch and tea at T.R.E. Dinner at Stow-on-the-Wold. Return to Oxford at 8.30 p.m. approximately.

THURSDAY 4 JULY IN OXFORD (continued)

9.30 a.m. DISCUSSION Subject (j); Land utilization, and conservation.
Place — Bio-chemistry Lecture Room.

2.15 p.m. LECTURE on Penicillin at the Pathology Laboratory, arranged by Sir Howard Florey, F.R.S.

4.00 – 6.30 p.m. VISITS The following laboratories will be open for inspection and informal discussions:

(i) Physical Chemistry Laboratory.
(ii) Bio-chemistry Laboratory.
(iii) Zoological Laboratory.
(iv) Physiological Laboratory.
(v) Pharmacology Department.

9 p.m. RECEPTION by President of Magdalen College.
Place — Magdalen College.

FRIDAY 5 JULY IN OXFORD AND IN LONDON

10 a.m. Leave by coach for London — route to be settled.

afternoon Arrive London.

SATURDAY 6 JULY IN LONDON

10 a.m. DISCUSSION Subject (g); Co-operation in the scientific field.
Place — The Royal Society.

4.30 p.m. RECEPTION and TEA, given by the Society for Visiting Scientists.
Place — 5 Old Burlington Street, London.

7.00 p.m. COCKTAIL PARTY, given by the Federation of British Industries.
Place — to be arranged.

SUNDAY 7 JULY IN LONDON

2.15 – 6.00 p.m. VISIT to the Port of London — Through the kindness of the Chairman, The Rt. Hon. Sir John Anderson, G.C.B., G.C.S.I., G.C.I.E., F.R.S., M.P., and members of the Port of London Authority, delegates to the Royal Society

SUNDAY 7 JULY IN LONDON (continued)

Empire Scientific Conference are invited to a cruise through the Port of London in the afternoon of Sunday, 7 July 1946. The number of invitations is limited by the capacity of the yacht to 110. Will you therefore please inform the Information Bureau at once if you wish to take part in this trip ; also whether you wish to bring a lady with you.

The programme is as follows :

High Water	LONDON BRIDGE	9.8 a.m. (B.S.T.)
2.15 p.m.	Leave Tower Pier in s.y. *St Katharine*. Proceed down river.	
3.15 p.m.	Arrive off King George V entrance and lock in. Cruise through Royal Docks system.	
4.15 p.m.	Lock out and proceed down river. Turn off Ford's Jetty (approximately). Return up river.	
6.00 p.m.	Disembark at Tower Pier.	

Afternoon tea will be served during the cruise.

MONDAY 8 JULY IN LONDON

10.00 a.m.	FINAL SESSION Place — University College, Gower Street, London.
1.00 p.m.	LUNCH, given by the Provost of University College, London. Place — University College, London.
2.30 p.m.	Scientific Departments of the College will be open to delegates.
2.30 p.m. – 6.30 p.m. (approximately)	DISCUSSION, arranged jointly with the British Association on the dissemination of scientific information to the general public.
6.30 – 8.00 p.m.	RECEPTION by The Royal Institution with demonstrations illustrating the history of researches carried out in the Institution and its Davy Faraday Laboratories.

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the arabic numerals the page.